



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

**BOSTON MEDICAL LIBRARY
IN THE
FRANCIS A. COUNTWAY
LIBRARY OF MEDICINE**

.

THE
JOURNAL
OF
ANATOMY AND PHYSIOLOGY
NORMAL AND PATHOLOGICAL.

CONDUCTED BY

G. M. HUMPHRY, M.D., F.R.S.,

PROFESSOR OF SURGERY, LATE PROFESSOR OF ANATOMY IN THE UNIVERSITY OF CAMBRIDGE;

SIR WILLIAM TURNER, M.B., LL.D., F.R.S.,

PROFESSOR OF ANATOMY IN THE UNIVERSITY OF EDINBURGH;

AND

J. G. M'KENDRICK, M.D., F.R.S.,

PROFESSOR OF THE INSTITUTES OF MEDICINE IN THE UNIVERSITY OF GLASGOW.

VOL. XXIV.
NEW SERIES.—VOLUME IV.

WITH TWENTY PLATES AND NUMEROUS WOODCUTS.

WILLIAMS AND NORGATE,
14 HENRIETTA STREET, COVENT GARDEN, LONDON;
AND 20 SOUTH FREDERICK STREET, EDINBURGH.

1890.

CATALOGUED,

m. j.

J. 21. 1891.

CONTENTS.

FIRST PART—OCTOBER 1889.

	PAGE
THE PROAMNION AND AMNION IN THE CHICK. By THOMAS W. SHORE, M.D., B.Sc., and J. W. PICKERING. (Plate I.)	1
TWO CASES OF VARIATION IN THE NERVE-SUPPLY OF THE FIRST LUMBRICAL MUSCLE IN THE HAND. By J. T. WILSON, M.B. Edin.....	22
OBSERVATIONS ON THE FUNCTION OF THE PROSTATE GLAND IN MAN AND THE LOWER ANIMALS. By JOSEPH GRIFFITHS, M.B., C.M. Edin. Part II. (Plates II., III.)	27
THE VERTEBRAL COLUMN OF A YOUNG GORILLA. By JOHNSON SYMINGTON, M.D., F.R.S.E. (Plate IV.)	42
FURTHER OBSERVATIONS ON THE INNERVATION OF AXILLARY MUSCLES IN MAN. By J. T. WILSON, M.B. Edin.	52
THE SIGNIFICANCE OF THE THIRD TROCHANTER AND OF SIMILAR BONY PROCESSES IN MAN. By Professor THOMAS DWIGHT, M.D., LL.D.....	61
SOME VASCULAR ANOMALIES OBSERVED DURING THE SESSION 1888-89. By Professor FRANCIS J. SHEPHERD, M.D.	69
THE FLEXORS OF THE DIGITS OF THE HAND. I. THE MUSCULAR MASSES IN THE FORE-ARM. By Professor BERTRAM C. A. WINDLE, M.A., M.D. Dubl.	72
THE GUSTATORY ORGANS OF <i>Belideus ariel</i> . By FREDERICK TUCKERMAN, M.D. (Plate V.).....	85
CONTRIBUTIONS TO THE COMPARATIVE OSTEOLOGY OF ARCTIC AND SUB-ARCTIC WATER-BIRDS. By R. W. SHUFELDT, M.D., C.M.Z.S. Part V. (Plates VI., VII., VIII.).....	89
THE PROPORTION OF BONE AND CARTILAGE IN THE LUMBAR SECTION OF THE VERTEBRAL COLUMN OF THE APE AND SEVERAL RACES OF MEN. By Professor D. J. CUNNINGHAM, M.D.	117
THE OCCASIONAL EIGHTH TRUE RIB IN MAN AND ITS RELATION TO RIGHT HANDEDNESS. By Professor D. J. CUNNINGHAM, M.D.....	127
FURTHER OBSERVATIONS ON THE DEVELOPMENT OF THE TASTE-ORGANS OF MAN. By FREDERICK TUCKERMAN, M.D.....	130

	PAGE
ABNORMAL VASCULAR SUPPLY TO THE LIVER. By HUMPHRY D. ROLLESTON, M.B. Cantab., M.R.C.P.....	132
PROCEEDINGS OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.....	135 (i)

SECOND PART—JANUARY 1890.

INTRAPARIETAL SULCUS OF THE BRAIN. By Professor D. J. CUNNINGHAM, M.D. (Plate IX.).....	135
GUSTATORY ORGANS OF <i>Procyon lotor</i> . By FREDERICK TUCKERMAN, M.D. (Plate X.).....	156
DRY COVER-GLASS MICROSCOPICAL PREPARATIONS. By Professor STIRLING, M.D.....	160
HEREDITARY MALFORMATION OF DIGITS. By J. WILKIE, B.A., B.Sc.....	167
CONTRIBUTIONS TO THE COMPARATIVE OSTEOLOGY OF ARCTIC AND SUB- ARCTIC WATER-BIRDS. By R. W. SHUFELDT, M.D., C.M.Z.S. Part VI. (Plates XI., XII.).....	169
STOMACH OF THE NARWHALE: THE BEARING OF ITS HISTOLOGY ON TURNER'S AND MAX WEBER'S NOMENCLATURE OF THE STOMACH OF THE ZIPHIOD AND DELPHINOID WHALES. By G. SIMS WOODHEAD, M.D., and R. W. GRAY.....	188
ACTION OF VARIOUS STIMULI ON NON-STRIPED MUSCLE. By G. H. COOKE, M.R.C.S. (Plate XIII.).....	195
ADDITIONAL NOTE ON THE INFLUENCE OF POSTURE ON THE FORM OF THE ARTICULAR SURFACES OF THE TIBIA AND ASTRAGALUS IN THE DIFFER- ENT RACES OF MAN AND THE HIGHER APES. By ARTHUR THOMSON, M.A., M.B.....	210
CASE OF HERMAPHRODITISM IN A COMMON FROG (<i>Rana temporaria</i>). By W. RAMSAY SMITH, B.Sc.....	218
ANATOMY OF THE TRANSVERSALIS MUSCLE AND ITS RELATION TO INGUINAL HERNIA. By KENNETH M. DOUGLAS, M.D., F.R.C.S. Edin.....	220
SPIRACLES OF THE PORBEAGLE SHARK (<i>Lamna cornubica</i>). By Professor EWART, M.D.	227
NEW METHODS OF IMBEDDING FRESH AND HARDENED TISSUES. By W. F. ROBERTSON	230
PROSTATE GLAND: ITS ENLARGEMENT OR HYPERTROPHY. By JOSEPH GRIFFITHS, M.B., C.M. Part III. (Plate XIV.).....	236
NOTE ON THE TRANSVERSE-HUMERAL, CORACO-ACROMIAL, AND CORACO- HUMERAL LIGAMENTS, &c. By C. GORDON BRODIE, F.R.C.S.....	247
THE CELL THEORY, PAST AND PRESENT. By Professor Sir W. TURNER.....	253

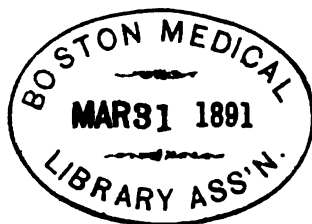
	PAGE
COAGULATION OF EGG AND SERUM ALBUMEN, VITELLIN, AND SERUM GLOBULIN, BY HEAT. By JOHN BERRY HAYCRAFT, M.D., D.Sc., and C. W. DUGGAN, M.B.....	288
TUMOUR IN THE FRESH-WATER MUSSEL (<i>Anodonta cygnea</i> , Linn.). By JOSEPH W. WILLIAMS.....	307
PROCEEDINGS OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.....	309 (vii)

THIRD PART—APRIL 1890.

THE COMPLETE FISSURES OF THE HUMAN CEREBRUM, AND THEIR SIGNIFICANCE IN CONNECTION WITH THE GROWTH OF THE HEMISPHERE AND THE APPEARANCE OF THE OCCIPITAL LOBE. By Professor D. J. CUNNINGHAM, M.D.	309
A FERMENTATION CAUSING THE SEPARATION OF CYTIN. By SHERIDAN DELÉPINE, M.B., B.Sc.	346
THE ORBITO-MAXILLARY FRONTAL SUTURE IN MAN AND APES, WITH NOTES ON THE VARIETIES OF THE HUMAN LACHRYMAL BONE. By ARTHUR THOMSON, M.A., M.B.	349
HUMAN NECK WITH THE ODONTOID PROCESS DISTINCT FROM THE BODY OF THE AXIS VERTEBRÆ. By Professor Sir WILLIAM TURNER.....	358
A CONTRIBUTION TO THE PATHOLOGY OF JOINT BODIES. By R. GLASGOW PATTESON, B.A., M.B. (Plate XV.).....	360
ABNORMAL REPRODUCTIVE ORGANS IN <i>Rana temporaria</i> . By OSWALD H. LATTEY, B.A. (Plate XVI.).....	369
FIBRO-PLATES AND INTERVERTEBRAL DISCS. By Professor CLELAND, F.R.S.	373
A CONTRIBUTION TO THE PHARMACOLOGY OF CURARE AND ITS ALKALOIDS. By JOSEPH TILLIE, M.D. (Part I.).....	379
VARIATION IN THE KIDNEY OF THE COMMON THORNBACK (<i>Raia clavata</i>): ITS NATURE, RANGE, AND PROBABLE SIGNIFICANCE. By Professor G. B. HOWES, F.L.S., F.Z.S. (Plate XVII.).....	407
CASE OF MALFORMATION OF THE HEART, WITH LARGE DEFICIENCY IN THE INTERAURICULAR SEPTUM, PATENCY OF THE FORAMEN OVALE AND STENOSIS OF THE AORTIC ORIFICE. By Professor GREENFIELD, M.D., F.R.C.P.	423
PHYSICAL NOTES ON THE MOTION OF THE BLOOD IN THE HUMAN ARTERIES. By Dr J. L. HOERWEG.....	434
INJURIES AND DISEASES OF NERVES. By ANTHONY A. BOWLBY, F.R.C.S.	472
PROCEEDINGS OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.....	475 (xiii)

	PAGE
<i>FOURTH PART—JULY 1890.</i>	
ACROMEGALY, WITH THE DESCRIPTION OF A SKELETON. By HENRY ALEXIS THOMSON, M.D., F.R.C.S.E.	475
HISTOLOGY OF THE SKIN OF THE ELEPHANT. By Professor FRED SMITH, M.R.C.V.S., F.I.C. (Plate XVIII.).....	493
CONTRIBUTION TO THE PATHOLOGY OF RETRO-BULBAR NEURITIS. By WILLIAM ALDREN TURNER, M.B. (Edin.), M.R.C.P. (Lond.).....	504
CONTRIBUTION TO THE PHARMACOLOGY OF CURARE AND ITS ALKALOIDS. By JOSEPH TILLIE, M.D. Part II.....	509
NATURE OF THE GIANT-CELLS OF TUBERCLE AND THE ELEMENTS ASSOCI- ATED THERewith, AS SEEN IN COMPARATIVE PATHOLOGY. By WALTER K. SIBLEY, M.B., B.C., B.A. Cantab. (Plate XIX.).....	517
STERNUM AS AN INDEX OF SEX, HEIGHT, AND AGE. By Professor THOMAS DWIGHT, M.D., LL.D.....	527
IRREGULAR UNION OF THE FIRST AND SECOND PIECES OF THE STERNUM IN MAN AND APES. By Professor THOMAS DWIGHT, M.D., LL.D.....	536
CONTRIBUTIONS TO THE COMPARATIVE OSTEOLOGY OF ARCTIC AND SUB- ARCTIC WATER-BIRDS. By R. W. SHUFELDT, M.D., C.M.Z.S. Part VII.....	543
VARIATIONS OF THE EXTERNAL PTERYGOID MUSCLE. By JOHN POLAND....	567
FATE OF THE NOTOCHORD AND DEVELOPMENT OF THE INTERVERTEBRAL DISC IN THE SHEEP, WITH OBSERVATIONS ON THE STRUCTURE OF THE ADULT DISC IN THESE ANIMALS. By E. W. CARLIER, M.B. (Plate XX.).....	573
DISPOSITION OF THE VERTEBRAL COLUMN IN HANGING (AND SWINGING) POSTURES. By JAMES CAGNEY, M.A., M.D.....	585
NOTE TO DR HOORWEG'S PAPER "PHYSICAL NOTES ON THE MOTION OF THE BLOOD IN THE HUMAN ARTERIES".....	592
PATHOLOGY OF GENU VALGUM, OR KNOCK-KNEE. By Professor HUMPHRY, F.R.S.	593
SENILE HYPERTROPHY AND SENILE ATROPHY OF THE SKULL. By Professor HUMPHRY, F.R.S.....	598
AN EASY METHOD OF DISSECTING THE EYEBALL. By HORACE DUNCAN, B.A. Cantab., M.B. Lond.....	599
SOME RECENT AND SOME NEW HISTOLOGICAL METHODS. By Professor WILLIAM STIRLING, M.D., Sc.D.....	601
NOTICES OF NEW BOOKS.....	611
INDEX.....	615
PROCEEDINGS OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND (WITH INDEX).....	617 (iv)

2044



Journal of Anatomy and Physiology.

THE PROAMNION AND AMNION IN THE CHICK.

By THOMAS W. SHORE, M.D., B.Sc., *Lecturer on Comparative Anatomy at St Bartholomew's Medical School*, and
J. W. PICKERING, *Scholar in Natural Science at St Bartholomew's Hospital.* (PLATE I.)

(From the Biological Department of St Bartholomew's Hospital.)

ALTHOUGH much has been written from time to time upon the development of the embryonic membranes in the *Amniota*, and particularly on those of birds and mammals, there are still some points which are obscure. In many respects the generally accepted descriptions of the formation of the amnion are inaccurate. Nor can it be said that any satisfactory explanation of the evolution and significance of the amnion has yet been given.

By Balfour¹ the amnion was believed to be connected in evolution with the allantois. Balfour's explanation of the nature of the allantois is that the urinary bladder of *Amphibia* has in *Sauropsida* acquired a respiratory function, and in *Mammalia* a nutritive one also. It has become precociously developed and extended in the embryo, and the amnion has been evolved *pari passu* with it as a simple fold of somatopleure, into which the urinary bladder grew as it increased and acquired a respiratory function. By an increase of this fold, the edges would meet over the embryo and might be conceived to have coalesced; and, finally, in order to allow room for the growing allantois and enable it to reach the surface, a separation of the two layers of the fold may be supposed to have occurred, and so to have given rise to the true and false amnions. As Balfour pointed out, the chief difficulty in this hypothesis is, that in actual ontogeny the head-fold and not the tail-fold of the amnion is the earliest developed and the most conspicuous part of the organ.

¹ *Comparative Embryology*, vol. ii. p. 256.

Ed. van Beneden,¹ however, has shown that in mammals the whole of the true amnion is formed from the tail region, and that the structure which for a considerable period of embryonic life encloses the head is not a true amnion, but a special structure which he has called the *proamnion*.

In describing the formation of the amnion in birds, Balfour² says:—"At the end of the first day of incubation, when the cleavage of the mesoblast has somewhat advanced, there appears a little way in front of the semilunar head-fold a second fold running more or less parallel or rather concentric with the first and not unlike it in general appearance, though widely differing from it in nature. This second fold gives rise to the amnion, and is limited entirely to the somatopleure. Rising up as a semilunar fold, with its concavity directed towards the embryo as it increases in height, it is gradually drawn backwards over the developing head of the embryo."³

Von Baër⁴ first described the formation of the amniotic folds and of the true and false amnions in birds and mammals, and, with the exception of one point, his description has been adopted by Bischoff,⁵ Kölliker,⁶ His,⁷ Balfour, and others. The diagrammatic schemes which are to be found in the standard works on embryology, and in the current anatomical and physiological text-books and manuals, have all been copied from the diagrams of von Baër as modified by Kölliker. Von Baër believed the amnion to be composed of epiblast only; Remak,⁸ Bischoff, and Kölliker have shown that the somatopleure layer of the mesoblast also enters into it. With this correction von Baër's description is that generally taught. Von Baër, as well as Bischoff, Kölliker, His, and Balfour, described the formation of the head-fold of the amnion as being in mammals of the same nature as that of the tail and lateral folds. According to them the formation and composition of the amnion is the same in mammals as in birds, the false amnion, however, being in the former represented only by the head-fold.

Ed. van Beneden and Julin,⁹ on the other hand, found that in the Rabbit the events which occur at the cephalic end of the embryo are different from those taking place at the tail, and that the *whole of the true amnion is formed from the tail-fold*. They found that the head, neck,

¹ "Recherches sur la formation des feuillets embryon. chez le lapin," *Arch. de Biologie*, vol. i., 1880.

² *Comparative Embryology*, vol. ii. p. 154.

³ In the above quotation, the italics are ours. They indicate the statements which we shall show require modification.

⁴ *Entwicklungsgeschichte d. Thiere*, Königsberg, 1828-37.

⁵ *Entwicklungsgeschichte des Kaninchen-Eies*, Braunschweig, 1842.

⁶ *Entwick. des Menschen*, &c., 2nd ed., vol. i., Leipzig, 1879; and *Grundriss d. Entwickelungs.*, Leipzig, 1880.

⁷ *Anatomie Menschlicher Embryonen*, Leipzig, 1880.

⁸ *Untersuchung. über d. Entwickl. d. Wirbelthiere*, Berlin, 1850-55.

⁹ "Recherches sur la formation des annexes fœtales chez les Mammifères," *Archives de Biologie*, vol. v. 1885.

and anterior part of the trunk of the embryo project deeply into the blastodermic cavity, pushing before it a membrane (the anterior part of the blastodermic vesicle) which is non-vascular, and is composed only of two blastodermic layers, epiblast and hypoblast. This membrane they call the proamnion. It is only a temporary structure, becoming progressively less as development advances, the tail-fold of the amnion becoming at the same time progressively greater until the whole embryo is enclosed in it. Van Beneden and Julin also point out that the *sinus terminalis* which Bischoff describes in the Rabbit as venous, is not so, but is arterial. Bischoff also described in the Rabbit two pairs of vitelline veins as in the Chick, but van Beneden and Julin showed that the posterior pair do not exist. As to whether a similar structure to the proamnion of mammals exists in other groups, van Beneden and Julin¹ say:—"Differentes figures de K  lliker permettent de supposer qu'il existe pendant une courte p  riode chez le poulet et les observations de Strahl et de Hoffmann permettent d'affirmer l'existence d'un proamnios chez les l  zard."

It seemed to us to be an important point to decide whether any structure of the nature of van Beneden and Julin's proamnion exists in birds, and to endeavour to explain the differences between the development of the embryonic membranes in the Rabbit and the currently accepted views as to their formation in Birds. A description of our observations on these and collateral points forms the subject of this paper.

Our method has been that generally employed in the investigation of the embryology of the Chick. The most satisfactory hardening reagents in our hands have been (a) the picric acid of Kleinenberg, and (b) a saturated solution of corrosive sublimate, followed in each case by alcohol of gradually increasing strength. The most reliable staining reagent for Chick embryos in our experience is cochineal, prepared according to the following formula:—"Take seven grammes of cochineal and seven grammes of alum, finely powdered, and thoroughly rub them together in a mortar; add seven hundred cubic centimetres of distilled water, evaporate down to four hundred, filter twice, and afterwards add four cubic centimetres of absolute alcohol."

After staining, our blastoderms have been dehydrated carefully, cleared in benzol or turpentine, saturated with hard paraffin, and embedded. They were cut in ribbons with a rocking microtome, the sections being chiefly about 10μ or $\frac{1}{16}$ th mm. in thickness.

The Blastoderm before the Formation of the Embryo.—The epiblast and hypoblast are formed in the manner generally described. After the establishment of the area opaca and area pellucida, the blastoderm is composed in the latter region of an

¹ *Loc. cit.*, p. 424.

epiblast made up of two layers of cells and a hypoblast of a single layer continued respectively in the area opaca, into a single layer of epiblast, and into the germinal wall of yolk-spherules. Between the epiblast and hypoblast in the area pellucida are a few scattered cells, which have probably been derived from the germinal wall. Practically, however, the whole of the mesoblast of the area pellucida is formed either from the primitive streak or the lateral parts of the hypoblast. At the time when the primitive streak first appears the area pellucida is nearly circular, but it soon becomes oval or pear-shaped, the anterior end being the broader. As the primitive streak forms, an opacity begins to appear in the posterior part of the area pellucida. This opacity extends forward towards the broad end of the area pellucida, and at the same time spreads out laterally so as to form the *embryonic shield*. In the whole of this opaque region the blastoderm is composed of mesoblast as well as epiblast and hypoblast. The opacity, however, does not extend so far forward as to reach the anterior margin of the area pellucida, but a crescentic space is left at quite the anterior part of this area, where the blastoderm is composed of epiblast and hypoblast only. This is shown in Plate I. fig. 1, which is a surface view of the area pellucida of a Chick's egg of about sixteen hours' incubation. As we shall show in the sequel, this region remains *diblastic* for a considerable period, and is equivalent to that part of the blastoderm of the Rabbit's blastoderm which becomes subsequently pushed in front of the sinking head to form the prominent proamnion of van Beneden and Julin. According to K  lliker, the formation of the mesoblast of the embryonic shield depends on the growth forwards of cells from the primitive streak.

Balfour admitted that this is to a certain extent true, but he showed that in the region in front of the anterior end of the primitive streak, the lateral parts of the mesoblast are formed from cells split off from the hypoblast. Balfour, however, appears to have overlooked the fact which K  lliker described, that, at the head end of the blastoderm and around the head end of the embryo of the Chick, the *mesoblastic layer is deficient*.¹ Our observations are in complete agreement with

¹ *Grundriss, &c.*, p. 47, fig. 40.

Kölliker on this point, and show that a condition similar to that described by van Beneden and Julin in Mammals is present in the Chick. The embryo subsequently forms between the anterior end of the primitive streak and the posterior margin of this diblastic area. The diblastic area is figured by Duval¹ in Chick blastoderms of various ages, though he lays no stress upon it and does not identify it with the proamnion. It is clearly shown in his figures of longitudinal sections of a twenty-one-hours' Chick, and in his surface views of Chicks of twenty-four hours' incubation and less. He figures it in longitudinal and transverse sections of the head region of Chicks up to forty-eight hours of incubation, but in one of fifty-two hours the diblastic region is no longer shown.

The Young Embryo and the "Head-fold."—When the medullary groove and folds appear as the first indications of the embryo, the diblastic area above described marks the anterior limit of the embryonic region. In the ordinary works on embryology the medullary folds are described as being continuous in front, and as being there limited by the "head-fold," which is described as a "tucking in or folding off of the embryo from the yolk-sac" in its anterior region.² In front of the semi-lunar head-fold there is described in an eighteen to twenty hours embryo a second fold concentric with it, which is the commencement of the amnion. In Plate I. fig. 2 is shown a drawing of the surface view of the area pellucida of a twenty-four-hours' Chick. Longitudinal sections of the blastoderm and embryo at about this stage will show that there is no trace as yet of the amnion, and that the structure described as a "fold" in front of the head-fold, on surface examination, is really the margin of the area opaca at its junction with the area pellucida. As to the so-called "head-fold," the appearances seen in such longitudinal median sections show that the head of the embryo lies over a portion of that part of the blastoderm which comprises epiblast and hypoblast only. From its position and relations there is no justification for the assumption that a process of "folding off" of the head region from the yolk-sac has taken place at all. It is more correct to describe the changes occurring in this region in a twenty-hours' Chick as a *growth forwards of the anterior*

¹ *Atlas de l'Embryologie*, 1889.

² *Comparative Embryology*, vol. ii. p. 138.

end of the embryo over the portion of the area pellucida which lies in front of it. This is rendered the more probable by the consideration that there has been a great increase of mesoblast and of the other layers at the head end of the embryo, and that comparatively little growth is taking place in the diblastic part of the area pellucida. It must certainly be admitted that the greatest growth and most obvious changes are taking place in the embryonic part of the blastoderm, and if this is so, there must result either a pushing forwards of the blastoderm in front, or the embryo must grow so that its head region lies above or below the front part of the blastoderm. From longitudinal and transverse sections, as well as from surface examination, it is clear that the head of the embryo lies *above* the blastoderm in front; and it is therefore reasonable to suppose that this has resulted not from a "tucking in" or "folding off" of the head, but from a *growth of it forwards*.

We take the view, then, that the structure called the "head-fold" results from a growth of the head forwards over the diblastic part of the blastoderm, and that a "folding off" does not, at any rate at first, occur.

The relations of the head of the embryo of a twenty-four-hour Chick to the diblastic area are well shown, as seen in surface view from the dorsal side, in fig. 2. In fig. 3 is shown a transverse section passing through the part of the head which is thus projecting forwards over the diblastic area. It is clear from this section that the blastoderm here contains only two layers of cells—epiblast and hypoblast. The formation of the anterior *cul-de-sac* of the foregut is seen to have commenced. This figure may be compared with the section shown in fig. 4, which is taken across the same blastoderm and embryo a little behind the posterior limit of the "head-fold." In this section mesoblast is clearly present in the area pellucida, and is continuous with that of the embryo. In sections taken in front of that shown in fig. 3 the diblastic area of the blastoderm is seen without the overlying head. A diblastic region in front of the head end of the embryo, of the same nature as that here described, is mentioned by Strahl¹ in Lizards.

¹ "Ueber die Entwicklung des Canalis myelo-entericus und der Allantois der Eidechse," *Schrift. d. Gesell. z. Beför. d. gesam. Naturwiss.*, Marburg, 1880.

The Proamnion.—Shortly after the head region of the embryo has attained to the degree of development seen in a twenty to twenty-four-hours' Chick, there begins a process of sinking of the embryo into the yolk-sac. This sinking first shows itself, as might have been expected, at the head end of the embryo, for in a Chick between thirty and thirty-six hours of incubation the head is distinctly depressed into the yolk-sac below the level of the rest of the embryo and of the blastoderm. The sinking head, as it advances towards the yolk-sac, depresses that part of the blastoderm over which it lies. If a Chick embryo of thirty-six hours' incubation be examined as a transparent object from the ventral aspect, it is quite clear that the head projects far more than the rest of the embryo, and that the projecting part is covered by a thin membrane, continuous laterally and anteriorly with the area pellucida of the blastoderm, and posteriorly traceable as far back as the developing vitelline veins, where it forms an abrupt ridge across the ventral side of the embryo. These points were well seen in the embryo of which fig. 5, Plate I., is a drawing. The anterior part of this membrane is the diblastic region of the blastoderm whose origin and relations have been described above. A longitudinal vertical section along the middle line of a thirty-six-hours' embryo will show that this membrane is still diblastic. The hypoblast forming its inferior surface is continuous with the hypoblast of the rest of the area pellucida and with the germinal wall in front, and is posteriorly traceable over the surface of the ridge above alluded to, into the hypoblast of the *cul-de-sac* of the foregut. Such a section is delineated in Plate I. fig. 6, which shows clearly that the head of the embryo is depressed so that its dorsal surface lies at a level with the surface of the blastoderm. The epiblast, which forms the superior layer of the membrane, is laterally and in front continuous with the epiblast of the rest of the blastoderm, and posteriorly is reflected into the epiblast of the ventral surface of the head, between which and the membrane a narrow *cul-de-sac* is seen. This membrane is the *proamnion*, and is identical in nature with the membrane thus named by Ed. van Beneden and Julin in mammals. It differs from the proamnion described by these embryologists in its extent, which in its turn depends on the degree of depression of

the head of the embryo into the blastodermic vesicle or yolk-sac. In the case of the Rabbit the head projects far more into the blastodermic vesicle than is the case in the Chick.

It is clear from the section shown in fig. 6 that there is **no** mesoblast in front of the embryo at this stage, except that which is not yet differentiated off from the germinal wall, and that there is no trace of a distinction into somatopleure and splanchnopleure. Nor has the head amnion-fold yet begun to be formed.

We now naturally seek for the cause or causes which determine the projection of the head into the yolk-sac. In the first place, it must be noted that the "cranial flexure," so characteristic of the head region of the higher vertebrate embryos, has begun to be formed in a thirty-six-hours' Chick (fig. 6), and one would naturally suppose that this flexure would lead to a projection of the head towards the yolk-sac. But it is clear from longitudinal sections that, though this doubtless has an effect in exaggerating the degree of projection into the yolk-sac, it is not by any means the sole cause. The whole head region has bodily sunk (fig. 6), and to an extent which cannot be accounted for by the cranial flexure only. In causing this actual sinking, the weight of the head region, which at this stage is, relatively to the rest of the embryo, highly developed, must doubtless be a factor. The natural tendency of gravity would also be assisted by the fact that at this stage, and more particularly at later stages, the yolk is not nearly so tense or resistant within the vitelline membrane as at an earlier stage. This is due to a partial liquefaction and absorption of yolk in the parts adjacent to the developing embryo. It is probable that the degree of resistance of the yolk determines to a great extent the amount of sinking of the head, for, in the case of the Rabbit, the head projects into the blastodermic vesicle, which contains only fluid, and is comparatively non-resistant, far more than in the case of the Chick, whose yolk-sac is almost filled by a resistant semi-solid yolk. It is probable, also, that there is yet another cause acting to determine to some extent the projection of the head into the yolk-sac. The forwardly-growing head of the embryo, which extends so as to lie over the pre-embryonic part of the area pellucida, would in its growth come in contact with and

meet the resistance of the vitelline membrane. There would thus be two forces acting on the head—(a) the growth of it forward in more or less a straight line coincident with or parallel to the long axis of the embryo, and (b) the resistance of the vitelline membrane acting along a line at right angles to its surface drawn from the point of contact of the head with it, and tending to force the head downwards into the yolk-sac.

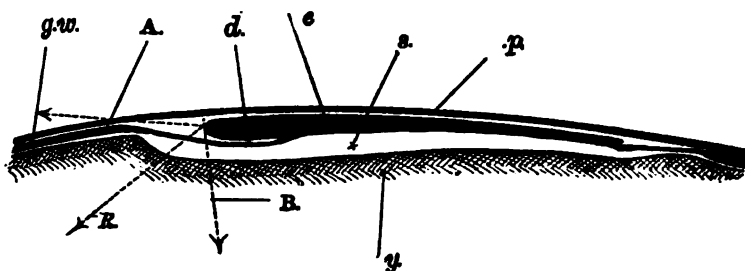


FIG. 7.—Diagram of a longitudinal section of a Chick blastoderm and embryo *in situ*. *p*, vitelline membrane; *e*, embryo; *g.w.*, germinal wall; *d*, diblastic part of blastoderm; *s*, space formed by liquefaction of the yolk; *y*, yolk; *A*, direction of growth of head of embryo; *B*, line of the forces of resistance of the vitelline membrane; *R*, the actual direction of growth resulting from the forces *A* and *B*.

The resultant of these two forces would be an actual growth of the head downwards and forwards towards the yolk-sac, and tending to push in front of it the diblastic part of the blastoderm. This is diagrammatically shown in fig. 7, where the arrow *R* shows the direction of the resultant growth. It is, again, natural to suppose that the diblastic region of the blastoderm which the sinking head depresses can offer but little resistance to this growth. It is possible, also, that the resistance of the vitelline membrane could not only explain in part the sinking of the head, but is also a possible cause of the cranial flexure itself. Whatever may be the primary cause of the sinking of the head region, it is certainly exaggerated at later stages by the cranial flexure.

The Head-fold of the Amnion.—We have quoted above (page 2) Balfour's description of the formation of the head amniotic fold, and have shown that "at the end of the first day of incubation" there is no trace of this fold. Nor is it to be seen even in a Chick blastoderm of thirty-six hours. Again, not only is

there in this region no cleavage of the mesoblast, but there is none present in front of the embryo at all, apart from the undifferentiated germinal wall. All ordinary current descriptions of the formation of the head amnion fold in the Chick agree in considering it to be a "rising up," or "dorsal inflexion," or "up-growth" of the epiblast and somatopleure of the precephalic part of the blastoderm. In describing the formation of the proamnion in the Chick we have shown that a sinking of the head of the embryo takes place. At the stage when the "head amnion fold" begins to be formed, this sinking is much more marked, and the extension downwards and forwards of the head is much more apparent. A longitudinal median vertical section through the head and blastoderm, when the anterior "amnion fold" is an obvious though small structure, *e.g.*, a forty-five to forty-eight-hours' Chick will show that there is no "rising up" of the front part of the blastoderm, but that the head, in its growth downwards and forwards, as determined by the considerations mentioned above, has begun to bury itself in a pouch of the blastoderm, which in its growth it has pushed in front of it. This is shown in fig. 8, which is a section of a forty-five-hours' Chick. With further growth, more and more of the head becomes thus enclosed in a pouch of the blastoderm, which, on a dorsal view of the embryo, takes the form of a membrane overlying the advancing head, and terminating posteriorly in a crescentic margin bridging over some part of the head, and whose position varies according to the degree of advance of the cephalic growth. Whilst these events are taking place, there has been formed, probably by differentiation of cells from the germinal wall, a definite layer of mesoblast in front of the diblastic proamnion. The mesoblast cells in this position have arranged themselves into a somatopleure and splanchnopleure, bounding an extra embryonic part of the coelom (fig. 8). With the forward growth of the head the hypoblast and splanchnopleure become more depressed than the corresponding epiblast and somatopleure, so that the latter appears as a prominent "fold" over the advancing head. In fig. 9 is shown a transverse section of the anterior part of the head of a forty-seven-hours' Chick enclosed in the pouch above described. The layers of cells which form the walls of the pouch are well seen. Superiorly, the wall is com-

posed of four layers of cells, an outer epiblast lined by somatopleure, and together forming a part of the *false amnion*, and an inner epiblast covered by somatopleure, which together form a part of the *true amnion*. Inferiorly, the inner epiblastic layer is seen to be continuous with the epiblast of the diblastic proamnion; and the inner layer of somatopleure is seen laterally and ventrally to be reflected into the splanchnopleure of the commencing vascular area. The deepest layer is hypoblastic, continued laterally into the germinal wall, and where it underlies the head, forming the deep layer of the proamnion. From figs. 8 and 9 it is clear that the "head-fold of the amnion," at any rate at first, is not the result of an "upward growth" of the superficial layers of the blastoderm, but *is due to the forward extension, accompanied by sinking in of the head, so as to be enclosed in a pouch of the precephalic blastoderm*. The inferior wall of this pouch is the *proamnion*; the anterior and dorso-lateral parts are the layers of cells which are ordinarily described as the "head amnion fold," and which subsequently form the head parts of the *true* and *false amnions*.

The Tail and Lateral Amnion Folds.—The apparent folding off of the tail region from the post-caudal part of the blastoderm is due to a backward growth of this region over the blastoderm, and is accompanied by the same sinking in as is seen at the head region. The so-called "tail fold" of the amnion is also, as far as we can make out, due to the same conditions acting at the tail region as those which produce the so-called "head amnion fold" at the cephalic region.

At a later stage the lateral amnion folds arise, and appear to us to be of the same nature as the head and tail amniotic folds, viz., the result of a sinking of the embryo towards the yolk-sac. That there is no "rising up" of a fold outside the embryo is clear from a transverse section of a Chick embryo and blastoderm at this stage. Fig. 10 is a transverse section through the trunk region of a fifty-eight to sixty-hours' Chick. From this drawing it is clear that the splanchnopleure and hypoblast form a "fold" at the sides of the embryo beneath the somatopleure and epiblast of the "amnion fold." So that, if there occurs any "rising up" of the blastoderm outside the embryo, it is not merely the somatopleure and epiblast which "rise up," but the

splanchnopleure and hypoblast also. In fact, neither of these membranes "rises up," but the embryo sinks bodily into the blastoderm, which at this stage accidentally happens to be composed of somatopleure and splanchnopleure, having a continuation of the coelom between them.

A similar "folding up" of the splanchnopleure and hypoblast is present at the head and tail ends of the embryo. In a ninety-six-hours' Chick, for example, if viewed from the ventral aspect, the sub-embryonic portion of the wall of the yolk-sac is seen to tuck in around the embryo in front, behind, and at the sides, so as to form around it an incomplete sac, beneath and separate from the true amnion, and then peripherally to be reflected into the rest of the area vasculosa. This is shown diagrammatically in fig. 11.

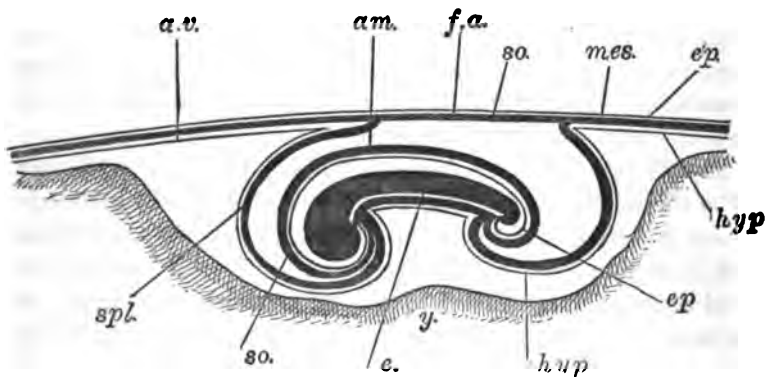


FIG. 11.—Diagram of a longitudinal section of the membranes of the Chick at about 100 hours' incubation:—*ep.*, epiblast; *mes.*, mesoblast; *hyp.*, hypoblast; *so.*, somatopleure of mesoblast; *spl.*, splanchnopleure; *f.a.*, false amnion; *am.*, true amnion; *e.*, embryo; *a.v.*, area vasculosa; *y.*, yolk.

The Closure of the Amnion Sac.—By examining from the dorsal aspect a number of Chick embryos of different stages, up to about sixty or sixty-five hours of incubation, it will be found that the anterior part of the embryo grows rapidly, depressing the anterior part of the blastoderm more and more; and the amnion fold will appear to be gradually drawn backwards over the dorsum of the embryo. But a careful examination, with measurements, will make it clear that *there has actually been no growth of it backward*, and that the forward progression of

the head has been the cause of the apparent backward growth of the posterior margin of the head amnion fold. That there is no actual growth of it backward is proved by the fact that the absolute distance from its posterior margin to the tail end of the embryo is no less, even a trifle greater, in a fifty to fifty-five-hours' Chick than at an earlier stage. Nor is the distance from the posterior margin of the "head amnion fold" to the anterior margin of the "tail amnion fold" less in a fifty-five to sixty-hours' Chick than in a younger one. This shows that the closure of the amnion sac is not due to a gradual approximation of the head and tail amnion folds. It is at the stage when the "lateral amnion folds" begin to meet over the embryo that the amnion sac commences to close. *Closure of the amnion sac is solely due to a linear coalescence of the margins of the "lateral amnion folds" from before backward over the dorsum of the embryo.* The line of this closure is often visible for a considerable time, as a thickening of the closed or partially closed amnion sac over the trunk of the embryo. A drawing of this, as seen in a sixty-two-hours' Chick embryo, is given in fig. 12. As might be expected, a transverse section at this stage shows a marked thickening of the epiblast in this region. This thickening is visible in such sections for from twelve to fifteen hours after the complete closure of the amnion sac, and along this line the margins of the somatopleure layer of the fold remain separate as long as the thickening lasts, so that the true and false amnions are unseparated from each other in this region for long after the amnion sac has closed. This line of union of the true and false amnions is only visible along the line of closure of the "lateral folds," and is absent in the region of the original "head and tail folds." It follows from this description that the right and left extra-embryonic portions of the cœlom are for a time not continuous with each other over the embryo in this region. The allantois may be seen in a Chick of about eighty-five-hours' incubation to occupy a large part of the *right* of these extra-embryonic halves of the cœlom.

The Vessels of the Area Vasculosa.—A short description of the arrangement of the vessels of the area vasculosa in the earlier stages of its existence is necessary in order to complete the description of the relations and to trace the fate of the pro-

amion. By about forty-five to forty-eight hours of incubation the circulation in the area vasculosa has become fairly well established. At this stage there is a *sinus terminalis*, which is undoubtedly venous, and in this respect differs markedly from the sinus of mammals, which van Beneden and Julin¹ showed to be arterial, and also from that of elasmobranch fishes, which Balfour proved to be arterial. From the sinus terminalis in front, where it is incomplete, there pass backwards two veins, one on each side of the head of the embryo, lying in the blastoderm at some distance from the head. These, which may be regarded as continuations of the sinus, are the *anterior vitelline veins*. Each terminates by joining with the *posterior vitelline vein* of the same side, just prior to the union of them at the venous end of the heart. A little behind the posterior vitelline, or omphalomeseraic veins, the two omphalomeseraic or vitelline arteries are seen running at right angles to the embryo, and terminating in the capillaries of the area vasculosa. If the ventral aspect of a forty-eight-hours' blastoderm, with its embryo, be examined, it will be seen that the membrane described above (page 7) as the proamion is at this stage bounded laterally by the anterior vitelline veins, anteriorly extends to the limit of the area pellucida, and posteriorly as far back as the line of reflection of the "head-fold" into the embryo. The relations of the anterior vitelline veins to it in the Chick are precisely the same as the relations of the omphalomeseraic veins of the Rabbit to the proamion as described by Ed. van Beneden and Julin, the difference in the two cases being one of degree of projection of the head covered by proamion. A reference to figs. 1, 2, 3, and 4 of plate xxii. of their paper will make this clear.

The subsequent changes which take place in the arrangement of the anterior vitelline veins in the Chick can be well seen by examination as transparent objects of Chicks from forty-eight to sixty hours of incubation. There takes place a progressive diminution in the size of the *left* anterior vitelline vein until it finally disappears, and the right alone remains to connect the *sinus terminalis* with the venous end of the heart. In a fifty-hours' Chick the left anterior vitelline vein is much smaller than the right, which arises from the sinus terminalis by two roots

¹ *Loc. cit.*, p. 381, and figs. 1, 2, 3, and 4 of plate xxii.

connected with the right and left halves of the sinus respectively, and carries the greater part of the current of blood from the sinus to the heart. In a fifty-five-hours' Chick the right anterior vitelline vein alone is present, and this is the case in all later stages, so long as this vein can be distinguished at all.

In the Rabbit, according to van Beneden and Julin, there occurs a similar gradual disappearance of the *left* omphalomeseraic vein. This is shown in figs. 3 and 4 of plate xxii. of their paper. In the case of the Rabbit the omphalomeseraic, or vitelline veins, curve forwards at the lateral margins of the proamnion, and mark the boundaries of what van Beneden and Julin call the "orifice amniotique," where the proamnion and caudal amnion folds are continuous with each other. The veins then diverge laterally in front of the embryo, to form more or less a semicircle concentric with the anterior part of the arterial sinus terminalis. There is little doubt that the omphalomeseraic veins of the Rabbit are equivalent to the anterior vitelline veins of the Chick, and that the venous semicircle, shown in van Beneden and Julin's figures, is the representative of the Chick's venous sinus terminalis. The large and well-developed posterior vitelline veins of the Chick are not represented in the Rabbit.

The Fate of the Proamnion.—In sections of a forty-five to forty-eight-hours' Chick, we have already seen that the proamnion is a well-marked structure, and an examination of a series of sections will enable one to map out exactly the extent of the diblastic region of which it is composed. It is bounded laterally by the anterior vitelline veins. These lie where the splanchnopleure of the area vasculosa is reflected into the somatopleure of the true amnion. Similar sections through the head region of Chicks of fifty to fifty-five hours will show that the width and extent of this membrane becomes progressively less by the extension between its layers of mesoblast (somatopleure and splanchnopleure carrying a prolongation of the extra-embryonic part of the coelom) from the anterior and lateral regions of the head part of the blastoderm, until, when the left anterior vitelline vein has disappeared, all trace of the diblastic proamnion has gone also. It has become completely penetrated with mesoblast. The membrane which covers the head of a sixty-hours' Chick, viewed from below, is therefore not a proamnion, but is now composed of two distinct parts—(a) a ventral layer made up of hypoblast and splanchnopleure, continuous behind with the corresponding layers of the embryo and in front with the mesoblast and hypo-

blast of the yolk-sac; (b) a deeper layer, composed of epiblast and somatopleure, continuous posteriorly with those layers of the embryo, and anteriorly forming a portion of the head part of the true amnion.

Van Beneden and Julin describe a similar disappearance of the proamnion in the Rabbit, which, though a very prominent structure on the tenth, eleventh, and twelfth days, has completely disappeared by the fifteenth. The position occupied by the proamnion is marked in a fifteen-days' Rabbit by a line occupied by the persistent right omphalomeseraic vein, and along this line the true amnion, formed as they show from the "tail amnion fold," is throughout the rest of gestation *attached to the area vasculosa*. They discuss two hypotheses to account for the disappearance of the proamnion—(a) that there has been a true atrophy of it, (b) that mesoblast has extended between the layers of which it is composed. Though they have not made out clearly which of these hypotheses is true, they are rather inclined to the former as it would better account for the attachment of the true amnion to the area vasculosa along the "cicatrix" of the proamnion.

As to the cause of the disappearance of this structure in the Chick, we are clear that there is an extension of mesoblast between the two primary layers of it, and we have not observed in the Chick any attachment of the true amnion to the area vasculosa in this region after the proamnion has gone. If it occurs at all, it is of very short duration.

Forces which produce the Amnion.—It has been shown that the "amniotic folds" of the Chick primarily owe their origin to a sinking of the embryo towards the yolk-sac. The forces which produce the sinking of the head have been shown to be—(a) the weight of the unsupported head projecting over the precephalic part of the blastoderm; (b) partial liquefaction of the yolk subjacent to the embryo; (c) the non-resistant character of the part of the blastoderm over which the head lies; (d) the resistance offered to the forward growth of the head by the vitelline membrane. These circumstances first of all lead to a bulging of the proamnion into the yolk-sac, and afterwards are the cause of the "head amnion fold." When the tail of the embryo has grown so as to overlie the post-caudal part of the blastoderm, the same conditions, though in a less marked degree, begin to act and to produce the "tail amnion fold." Similarly, at a later stage, the "lateral amnion folds" are formed. These conditions

seem to us to be the main, if not the sole, causes of the actual production of the amnion in the Chick. We believe that the same causes have been capable of leading to the gradual evolution of the amnion in *Sauropsida* and *Mammalia*, and that the extent to which the structure develops in different types, and the exact details of its formation, are due solely to variations in the exact mechanical conditions present in different cases. We are therefore strongly of opinion that the idea of Balfour, that the amnion has been evolved *pari passu* with the allantois, does not represent the evolution of this organ. Balfour himself recognised the chief difficulty in his hypothesis, viz., that the "head-fold" of the amnion is the most conspicuous part of the organ. This fact is most satisfactorily explained on the view that the amnion has resulted from mechanical causes. Balfour and other embryologists seem to have overlooked the fact, that the embryo *sinks* toward the yolk-sac, and thus have regarded the "amniotic folds" as "rising up" from the blastoderm.

J. A. Ryder¹ takes the view, that one of the mechanical conditions which have led to the formation of the "amniotic folds," is a rigid zona in presence of the active forces of growth. He points out that in some osseous fishes there are rudiments of head and tail amniotic folds. These are present in those osseous fishes whose ova are closely invested by a rigid zona; but in a few teleosts the zona is looser and less resistant, and in them no such rudiments are found. He further explains the early formation and greater extent of a head amnion fold, as being due to a precocious development of the cranial flexure.

Ed. van Beneden and Julin, from their researches on mammals, regard the amnion as having resulted from mechanical causes. They say²:—"Dans notre opinion, la cause déterminante de la formation de l'enveloppe amniotique réside dans la descente de l'embryon, déterminée elle même par le poids du corps."

Haddon³ says:—"It is now generally admitted that the amnion was primitively caused by the embryo sinking into the yolk-sac by its own weight. The protection to the embryo by the formation round it of what is virtually a water-sac, resulted in the precocious development of the amnion before the embryo in its ontogeny had any appreciable weight." We agree entirely with the first part of this quotation, but not with the second. Our observations lead us to the belief that the amnion is not "precociously developed," but that in actual ontogeny its formation is due to purely mechanical causes, at any rate in the Chick.

¹ "The Origin of the Amnion," *American Naturalist*, vol. xx., Philadelphia, 1886.

² *Loc. cit.*, p. 425.

³ *Introduction to the Study of Embryology*, 1887, p. 85.

Relation of the Head Amnion Fold to the Cranial Flexure.

The remarkable form of the head of a vertebrate embryo, viz., the prominent flexure of it to the ventral side, was discussed by Balfour in endeavouring to throw light on the nature of the chordate ancestor. He considered it unlikely that this form of the head of vertebrate embryos could represent the character of this region in any pre-existing ancestor. This type of head is a much more prominent feature in the embryos of the *Amniota* than in those of lower forms. In fact, the only group outside the *Amniota* in which the cranial flexure is a marked feature is the *Elasmobranchii*. In all these cases, as Balfour pointed out, the development in the main takes place within the egg, and in those types in which there is a larval development the cranial flexure is by no means a marked object. The cranial flexure then is confined almost to the *Amniota*, and it is natural to inquire whether there is any connection between it and the amnion of the nature of cause and effect. We do not think that the cranial flexure was the primary cause of the amnion, though without doubt it has led to an earlier formation of the head amnion fold and to an exaggeration of it during the earlier phases of embryonic life. It must be pointed out that all the *Amniota* have either a large-yolked egg or one which has been derived from a large-yolked ancestor, and that the embryo is therefore formed on a comparatively limited part of the upper side of the egg. This we consider to have been the first circumstance leading to the production of an amnion. Given this condition—a relatively large yolk and a small embryo—so soon as the growth of the embryo has caused it to have a definite appreciable weight, and the yolk has in consequence been partly absorbed, the natural tendency of gravity will lead to a sinking of the embryo and the production of the amniotic “folds.” The cranial flexure, therefore, has probably only a secondary effect in the production of the amnion.

Summary and Conclusions.

1. A diblastic proamnion of the same nature as that of Mammals is present in the Chick.
2. It is found in the Chick from shortly after the establishment of the primitive streak up to about fifty hours of incubation.
3. It is bounded laterally by the anterior vitelline veins, and thus agrees with the proamnion of Mammals, which is bounded by the omphalomesenteric or vitelline veins.
4. The sinus terminalis, unlike that of Mammals, is venous.
5. The "head-fold" results from a forward growth of the head over the diblastic proamnion, and not by a "folding off" from the blastoderm.
6. The head, tail, and lateral amnion folds are *not* formed by a "rising up" of the blastoderm around the embryo, but are determined by the growth of the embryo and its sinking towards the yolk-sac.
7. The amnion in ontogeny owes its origin to purely mechanical causes, the most important of which are—the weight of the embryo and the resistance of the zona in the presence of the active forces of growth.
8. The closure of the amnion sac is due solely to the meeting and coalescence of the "lateral amnion folds" over the dorsum of the embryo, and a thickening marks this coalescence for a considerable period.
9. The proamnion in the Chick disappears at about fifty hours' incubation, owing to the extension of mesoblast between its layers. It subsequently contributes to the ventral part of the head end of the true amnion and to the wall of the yolk-sac.
10. The cranial flexure is a cause of the early formation and exaggeration of the head amnion "fold."

BIBLIOGRAPHY.

1. VON BAER, *Entwicklungsgeschichte d. Thiere*, Königsberg, 1828–37.
2. F. M. BALFOUR, *Comparative Embryology*, London, 1882.

3. ED. VAN BENEDEN, "La Maturation, la fecondation et la segmentation de l'œuf chez les Cheiroptères," *Arch. de Biologie*, vol. i., 1880.
4. ED. VAN BENEDEN, "Recherches sur la formation des feuilletts embryonnaires chez le lapin," *Arch. de Biologie*, vol. i., 1880.
5. ED. VAN BENEDEN and CH. JULIN, "Recherches sur la formation des annexes fœtales chez les Mammifères," *Arch. de Biologie*, vol. v., 1885.
6. BISCHOFF, *Entwicklungsgeschichte des Kaninchen-Eies*, Braunschweig, 1842.
7. COSTE, *Embryogenie Comparée*, Paris, 1837.
8. M. DUVAL, "Etudes sur l'origine de l'allantoïde," *Revue des Sciences naturelles*, vol. vi., 1877.
9. M. DUVAL, "De la formation du blastoderme dans l'œuf d'oiseaux," *Annales des Sciences naturelles*, vol. xviii., 1882.
10. M. DUVAL, "Etudes histologiques et morph. sur les annexes des embryons," *Jour. de l'Anat. et Physiolog.*, vol. xx., 1884.
11. M. DUVAL, *Atlas de l'Embryologie*, 1889.
12. FOSTER and BALFOUR, *Elements of Embryology*, 1883.
13. HADDON, *Introduction to the Study of Embryology*, 1887.
14. HIS, *Anatomie Menschlicher Embryonen*, Leipzig, 1880.
15. KÖLLIKER, *Entwickel. des Menschen und der höheren Thiere*, Leipzig, 2nd ed., 1879.
16. KÖLLIKER, *Grundriss der Entwicklungs.*, Leipzig, 1880.
17. C. S. MINOT, Article "Amnion," *Reference Handbook of Medical Sciences*, New York, 1885.
18. QUAIN, *Elements of Anatomy*, vol. ii.
19. REMAK, *Untersuch. ueber d. Entwickl. d. Wirbelthiere*, Berlin, 1850-55.
20. J. A. RYDER, "The Origin of the Amnion," *American Naturalist*, vol. xx., Philadelphia, 1886.
21. SALENKA, *Studien über Entwickl. der Thiere*, iii.; *Die Blätterumkehrung im Ei der Nagethiere*, Wiesbaden, 1884.
22. STRAHL, "Ueber die Entwicklung des Canalis myeloentericus und der Allantois der Eidechse," *Arch. f. Anat. und Phys. Anat. Abtheil.*, 1881.

EXPLANATION OF PLATE I.

Fig. 1. Surface-view of the area pellucida after sixteen hours' incubation. *pr.s.*, primitive streak; *tr.*, triblastic region of the area pellucida; *d.*, diblastic region; *e.r.*, position in which the embryo will form.

Fig. 2. Surface-view of the area pellucida of a twenty-four-hours' Chick. *pr.s.*, primitive streak; *m.g.*, medullary groove; *p.*, mesoblastic somite; *m.f.*, medullary fold; *h.f.*, so-called head-fold; *d.*, diblastic proamnion.

Fig. 3. Transverse section of the anterior part of head of a twenty-four-hours' Chick. *ep.*, epiblast; *hyp.*, hypoblast; *mes.*, mesoblast; *m.g.*, medullary groove; *f.g.*, fore-gut; *g.w.*, germinal wall; *d.*, diblastic proamnion.

Fig. 4. Transverse section through the same Chick just behind the "head-fold." *ep.*, epiblast; *hyp.*, hypoblast; *mes.*, mesoblast of area pellucida; *mes'*, mesoblast of the embryo; *m.g.*, medullary groove; *g.w.*, germinal wall; *n.*, notochord.

Fig. 5. Ventral view of the embryo of a thirty-six-hours' Chick's egg. *pr.a.*, proamnion covering the head; *h.*, head; *ht.*, heart; *v.*, vitelline vein; *p.*, mesoblastic somites; *n.*, notochord; *r.*, margin of reflection of hypoblast of blastoderm into the fore-gut; *l.*, marks the line of reflection of the epiblast of the proamnion into that of the embryo.

Fig. 6. Longitudinal median section of a thirty-six-hours' Chick; *ep.*, epiblast; *g.w.*, germinal wall; *hyp.*, hypoblast; *mes.*, mesoblast; *p.c.*, pericardial cavity; *ht.*, heart; *f.g.*, fore-gut; *f.b.*, fore-brain; *m.b.*, mid brain; *h.b.*, hind brain; *pr.am.*, proamnion.

Fig. 7. See p. 9 of text.

Fig. 8. Longitudinal median section of a forty-five-hours' Chick. *ep.*, epiblast; *hy.*, hypoblast; *mes.*, mesoblast; *so.*, somatopleure; *spl.*, splanchnopleure; *h.a.f.*, head amnion fold; *p.p.*, coelom; *f.g.*, fore-gut; *f.b.*, fore-brain; *pr.am.*, proamnion; *p.c.*, pericardial cavity; *ht.*, heart.

Fig. 9. Transverse section of the head of a forty-seven-hours' Chick. *ep.*, epiblast; *hyp.*, hypoblast; *so.*, somatopleure; *spl.*, splanchnopleure; *p.p.*, coelom; *f.b.*, fore-brain; *h.b.*, hind brain; *op.*, optic vesicle; *n.*, notochord; *am.*, true amnion; *pr.am.*, proamnion; *f.am.*, false amnion.

Fig. 10. Transverse section of the trunk of a fifty-eight hours' Chick. *ep.*, epiblast; *hyp.*, hypoblast; *so.*, somatopleure; *spl.*, splanchnopleure; *i.*, intermediate cell mass; *pr.*, mesoblastic somite; *n.c.*, neural canal; *n.*, notochord; *ao.*, aorta; *v.a.*, vitelline artery (right); *p.p.*, coelom; *l.a.f.*, lateral amnion fold.

Fig. 11. See p. 12 of text.

Fig. 12. Surface view of a sixty-two-hours' Chick. *h.*, head covered by the head amnion fold; *ht.*, heart; *l.a.f.*, lateral amnion fold; *t.a.f.*, tail amnion fold; *p.v.*, posterior vitelline vein (right); *a.v.*, anterior vitelline vein (median); *v.a.*, left vitelline artery; *s.*, space uncovered by amnion; *l.*, thickening of the amnion marking the line of closure of the lateral amnion folds; *c.*, capillaries of the area vasculosa.

**TWO CASES OF VARIATION IN THE NERVE-SUPPLY
OF THE FIRST LUMBRICAL MUSCLE IN THE
HAND.** By J. T. WILSON, M.B. (Edin.), *Demonstrator of
Anatomy in the University of Sydney, New South
Wales.*

IN a paper in this *Journal* (vol. xxi. p. 575) on the nerve-supply of the lumbrical muscles, Dr St John Brooks describes and tabulates his observations, embracing instances of all the known variations in the innervation of these muscles. According to his table, it appears that the first lumbrical muscle in the hand was the only one of the four whose nerve-supply was quite constant. I was therefore interested to find, on recently dissecting the left hand of an Australian aboriginal, that the nerve-supply of this muscle showed a departure from the normal arrangement exactly comparable to that so frequently noticed in the case of the other members of the series. The condition was as follows:—The first lumbrical muscle received on its superficial aspect the usual branch of supply from the branch of the median nerve proceeding to the radial side of the index finger, but, in addition, there was found entering its deep aspect a nerve twig, which was traced deeply to that branch of the deep division of the ulnar nerve which supplies the first dorsal interosseous muscle. This fine branch passed downwards in the hand upon the surface of the muscle, probably supplying twigs to it, and lying beneath the fascia covering the interosseous muscles. It then pierced this fascia, and passed forwards to gain the deep surface of the first lumbrical muscle.

The corresponding muscle in the right hand was also carefully examined, but was not found to possess a double nerve-supply. On this (right) side, the only departure from the commonly described arrangement was that the third lumbrical muscle was innervated from the median as well as from the deep division of the ulnar nerve.

The case just described is of considerable interest, occurring as it does in a specimen of one of the lower races of men, among

whom the progressive replacement of the median by the deep ulnar nerve in the supply of the lumbrical muscles, which Dr Brooks' theory postulates, might reasonably be expected to be best advanced.

Since the foregoing account was written I have had the good fortune to dissect another hand presenting features very similar to those described above. This was the hand of a European subject which had been preserved from a former session, so that I was unable to identify it as belonging to a particular body. In this (a right) hand the first lumbrical muscle derived, as usual, a nerve of supply from the digital branch of the median to the radial side of the index finger. Just before entering the belly of the muscle, this superficial lumbrical nerve furnished a number of filaments which also penetrated its superficial surface, while it itself pierced the muscle so as to effect a communication in its substance with a nerve entering its deep aspect. This deep nerve was traced backwards through the layer of fascia covering the first dorsal interosseous muscle, and some distance below the adductor pollicis muscle, to a point where it emerged from the substance of the former muscle. Traced within that muscle, the nerve in question was seen to arise from that branch of the deep division of the ulnar nerve which traverses and supplies the muscle. Followed towards its junction with the twig from the median, this deep lumbrical nerve was found to furnish several delicate filaments to the deep surface of the lumbrical muscle, just as the median nerve was seen to do in the superficial aspect, so that each of the elements forming the nervous communication thus plainly contributed to the supply of the muscle.

Where the deep lumbrical nerve was placed in front of the neck of the metacarpal bone of the index finger it was observed to give quite a number of filaments, which were distributed, mostly with minute branches of the large radial indicis artery, partly to the metacarpo-phalangeal joint of the index finger, and, more doubtfully to that of the middle finger. Some extremely minute fibres may also have passed farther down the index finger, but this was not definitely ascertained.

Further examination of the lumbrical nerves in this hand showed that, while the fourth lumbrical muscle was supplied

solely by a branch from the deep division of the ulnar nerve, and the second solely by a branch from the median nerve, the third, like the first, muscle possessed a double nerve-supply, being provided with a filament from the innermost digital branch of the median nerve in addition to its branch from the deep ulnar. Such a mode of innervation of the third lumbrical muscle has been shown by Dr Brooks¹ to be an extremely common one, and was thus exhibited by two out of three hands referred to in this paper. There was in the case of this muscle also a large and definite communication through its substance between its two nerves of supply, though each contributed filaments to the muscle substance. Dr Brooks seems to have found such a communication pretty constantly in cases where he dissected out a double nerve-supply. Indeed, as he mentions no exception, it seems highly probable that a junction is always present where the muscle derives its supply from two sources. Such a law of nervous communication may probably be laid down as governing all cases of double innervation of muscles. The innervation of the trapezius and sternomastoid offer familiar examples.

The features of both cases of anomalous innervation of the first lumbrical muscle, narrated above, are almost identical. In the first (aboriginal) subject, the deep nerve lay on the surface of the abductor indicis muscle, but beneath the fascia covering the muscle, while in the second case it emerged from amongst the fibres of the same muscle. But in both cases it was a twig from the same nerve, and in other respects the relations of the two nerves were closely similar. The occurrence of the anomaly proves that the first, like the other lumbrical muscles in the hand, is not exempt from occasional variation in its mode of innervation.

In the paper already referred to, Dr Brooks offers a theory explanatory of the occurrence of these variations of the lumbrical nerves. His hypothesis is founded on Professor Cunningham's idea² of a gradual "encroachment" by the external plantar nerve in the foot on the domain of the internal plantar, and it seeks to explain the latter tendency, and a corresponding tendency in the hand towards encroachment on the domain of

¹ *Loc. cit.*

² *Journal of Anatomy*, vol. xvi. pp. 1 et seq.

the median nerve by the deep branch of the ulnar, by the aid of the principle of natural selection. In so far as a supposed orderly character of the change is suggested (progressive from within outwards in the hand), the foregoing cases will hardly tend to support the hypothesis. Still the theory may, in other respects, be a credible one, although it is hard to see how such trifling changes can have had any influence in securing "survival."

The question as to what constitutes the precise nature of the morphological change in such a variation, and in variations of the lumbrical nerves in particular, is discussed in a paper in the issue of this *Journal* for January 1889, by Messrs Young and Robinson. These writers suggest two alternative explanations; either (a) that the myotomes concerned in the formation of a muscle have varied, the change being accompanied by a corresponding change in the nerve-supply; or (b) that a different path is chosen by the nerve-fibres in the case of an anomalous innervation. In regard to the first alternative, it is evident that if we adopt it, we, in effect, deny the true homology, say, of a lumbrical muscle in one hand with the corresponding muscle in another, when it has a different nerve-supply. In such a case, the two muscles are at most only homodynamous, *not* morphologically identical. This, of course, is possible, but, in the case (e.g.) of the intrusive muscles of the pes, cited by Cunningham as furnishing a weighty objection to such theories, the true homology of the corresponding muscles was established by every test of homology, save the one which was *sub judice*. A view, then, which negatives the true homology of corresponding muscles in different individuals on the bare testimony of different nerve-supply may, I think, be dismissed.

The second alternative stated above (b) is, of course, that for which Professor Cunningham contends, and of the validity of which at least, in many cases, we have indubitable proofs, some of which are cited by him. I have recorded a case (*Journal of Anatomy*, April 1889), in which the nerve to the quadratus femoris was observed supplying the upper 2 inches or more of the adductor magnus muscle. Now, it would surely be absurd to hold that this apparent portion of the adductor magnus, inseparable from the rest of the muscle, and having the

origin, insertion, position, and relations of the upper part of a normal adductor magnus, was yet morphologically a part of the quadratus femoris, which yet was also present in *its* usual position and relations, separated from the adductor magnus by the terminal branch of the internal circumflex artery. But in accordance with the second alternative explanation, it seems not at all difficult to understand how that sector of the deep pub-ischio-femoral mass of muscle in the thigh, called upper part of adductor magnus, should receive its nerve-fibres by the same path with those supplying a more posterior (*i.e.*, caudal), but adjacent sector of the same pub-ischio-femoral mass, *i.e.*, quadratus femoris. *Why* such a transference of fibres from one path to another should occur in the first instance is, of course, obscure. Excluding those variations upon which the facts of comparative anatomy throw some light, enabling us to view them as in some sense "reversions," the first occurrence of such phenomena must, for the present, be set down under the safe category of "variations due to the nature of the organism." I think, therefore, that the facts at our disposal in regard to the phenomena of anomalous nerve-supply warrant the following among other conclusions:—(1) that the causes of their first occurrence (as of most variations in organisms) are obscure, although (2) some may be explicable as manifestations of a tendency to revision; (3) that the essential morphological character of such variations is in all probability a transference of nerve-fibres from one path to another, often an adjacent one, or one frequented by nerve-fibres, subserving related functions; (4) that, given original variation, natural selection may operate in the perpetuation of advantageous varieties, though it often seems inadequate to regard mere survival as the sole agent in the process.

OBSERVATIONS ON THE FUNCTION OF THE PROSTATE GLAND IN MAN AND THE LOWER ANIMALS. PART II. By JOSEPH GRIFFITHS, M.B., C.M. Edin., *Assistant to the Professor of Surgery in the University of Cambridge.* (PLATES II, III.)

IN a former paper, entitled "Observations on the Anatomy of the Prostate," which appeared in this *Journal*, April 1889, I drew attention to the development of this gland, especially during the period of life from birth to adolescence, and pointed out the manner in which the lateral lobes of the gland during that time came to encircle completely, or almost completely, the first part of the urethra. I further indicated the close relation that exists between the glandular and the muscular structures, and the part played by the latter in expelling the accumulated secretion of the gland tubules into the urethra. In the present paper I wish to bring forward certain facts, chiefly anatomical, which will afford further evidences in support of the view I have put forward regarding the nature and function of the prostate gland in Man and in the lower animals.

These facts have been derived mainly from observations on the prostate in the lower animals, because in many of them the generative function is in abeyance for the greater part of the year, and consequently the glands concerned are *inactive*, while for a time, which varies in each kind, the generative function again becomes *active*. In such animals an opportunity is afforded to examine and trace the changes in these glands from their *inactive* or *quiescent* state to that of *activity*. This I have done in the Mole and Hedgehog, both of which show changes of a very marked degree in the generative apparatus at each *rutting* season.

I propose to give also the results of an inquiry into the changes which the prostate undergoes after complete castration, by which I mean removal of both testicles, in the domesticated animals and in Man; and then to make a general summary of the facts thus elicited.

I have examined the prostates of the Mole and Hedgehog at

stated intervals, namely, the middle of each month from October to May. But as it is quite unnecessary to describe each specimen, I have selected two extremes and an intermediate state. These extremes correspond to the *active* and *inactive* states of the sexual function respectively.

John Hunter was, I believe, the first to draw attention to the periodical changes in the sexual glands of birds and some mammals; and it is to these changes, especially as they affect the prostate gland in the examples above mentioned, that I wish to allude.

In the *Works of John Hunter*, edited by J. F. Palmer (vol. iv. p. 29), is the following observation:—"In the Mole the prostate gland in winter is hardly discernible, but in the spring becomes very large and filled with mucus." This was confirmed by Owen (*Comp. Anat.*, vol. iii. p. 656), who adds "that the prostate gland in the Mole begins to increase in February, and acquires an enormous size, and conceals the urinary bladder towards the end of March." Owen further observed that similar changes occurred in the prostate and other accessory sexual glands of the Hedgehog.

I have examined the generative organs of the Mole and Hedgehog, in and out of the rutting season, and found the above observations to be correct. All I have to add are the histological changes at the different periods.

During the winter months the testis and all the accessory sexual glands are small, and are in what may be called a *state of rest* or of *quiescence*; but during the spring or summer months they are many times larger, and are then in a state of functional *activity*; I would therefore, for convenience in description, call the former the *quiescent* state, and the latter the *active* state of the gland.

THE PROSTATE IN THE MOLE.

Quiescent State.

A full-grown male was killed on the 15th of November 1888, and the generative organs removed and placed in strong spirit. The prostate gland formed a small unpaired whitish mass of uniform consistency, about a line and a half across, which was situated on the anterior or ventral aspect of the first portion of

the urethra, immediately in front of the neck of the urinary bladder (see Plate II. figs. 1, 2, 3).

Under the microscope this is seen to be composed of a great number of distinct tubules, which are bound together by delicate, loose, connective tissue, supporting the blood-vessels and nerves. Each tubule is made up of two coats, an *inner*, which bears the glandular epithelium, and an *outer*, which forms a complete and continuous sheath. The *inner* consists of delicate connective-tissue, lined by a single layer of small cubical epithelial cells, which consist of clear protoplasm, and contain a large round granular nucleus. In some of the tubules this coat is thrown into slight longitudinal folds. The *outer* coat, forming a sheath to the tubule, is made up of a thick layer of long spindle-shaped cells, similar in all respects to connective-tissue cells, arranged concentrically round each tubule (see Plate III. fig. 7). Such is the histology of the prostate during the early winter, and not until February is there any change visible either to the naked eye or under the microscope. I shall, therefore, dismiss at once the state of the prostate during December and January, and proceed to describe its state in the month of February.

Intermediate Stage.

A full-grown male was killed on the 15th of February 1889, and the organs were removed and prepared as in the former case. The prostate was about three times as large as that in the month of January, and there were slight evidences of the enlargement of each tubule (see Plate III. fig. 8).

Under the microscope the same structures are seen as in state I., but the tubules had grown and are much larger and more closely packed together. In the *inner* coat the longitudinal folds, seen only in a few examples in the quiescent state, are very marked, and into each fold a fine process of connective-tissue extends from the outer or non-epithelial part of this coat. Some of these folds show a subdivision into two lesser folds near their free ends. The epithelial lining is no longer composed of the cubical but of columnar-shaped cells, and between their tapering attached ends there are numerous small round cells. In only a few of the tubules a small amount of mucus

had formed and filled the lumen. The *outer* coat consists, not of cells identical with connective-tissue cells, but of well-developed granular non-striped muscle cells, forming a thick layer. These muscle cells contain rod-shaped nuclei, and take on the characteristic yellowish-brown stain with picrocarmine (see Plate III. fig. 8).

Active Stage.

A full-grown male, killed on the 15th of March 1889. The prostate gland now formed a mass many times the size of that in the quiescent state, and measured nearly $\frac{3}{4}$ of an inch across. It was visibly composed of a number of small tortuous tubules, which were united together by a small amount of delicate connective-tissue. From the front the enlarged, now active, prostate quite concealed the urinary bladder (see Plate III. fig. 9).

Under the microscope the chief alterations are to be found in the tubules. These had grown during the last month or six weeks to many times their original size, and the inner coat had become gradually more and more complicated. The longitudinal folds which were just beginning to divide in the intermediate state, had gone on dividing and subdividing until each had produced a kind of filamentous tree, projecting free into the lumen of the tubule. In this way the extent of surface covered by epithelium had been enormously increased, and the epithelium now constituted a single layer of tall columnar epithelial cells, with finely granular protoplasm, and a round nucleus near the attached end. Between the attached ends of adjacent cells there are small round granular cells, which in all probability replaces the columnar ones whenever they became exhausted and cast off. The *outer* coat consists of perfectly developed, non-striped, muscle cells. This formed a thick, strong, muscular coat capable of expelling the accumulated secretion of the gland-tubules (see Plate III. fig. 9).

The central lumen of each tubule was occupied by a coagulum (resulting from the action of the spirits) mainly composed of a more or less homogeneous substance like *mucin*, and a great many small round cells resembling leucocytes.

THE HEDGEHOG.

Quiescent Stage.

A full-grown male was killed in the middle of December 1888. The generative organs were removed and prepared as those of the Mole. The prostate gland formed a small bilobed mass on the ventral aspect of the beginning of the urethra, just in front of the neck of the bladder (see figs. 4, 5, 6).

Under the microscope each lobe was seen to consist of a number of distinct tubules, separated from one another and bound together into one mass by a considerable amount of loose fibrillar connective-tissue. Each tubule is composed of two coats, one *inner* and one *outer*. The *inner*, like that in the Mole, is formed of connective-tissue lined by a layer of low cubical epithelium; and the *outer* of a thick layer of concentrically arranged long spindle cells, which, in this animal, as well as in the Mole, are destined to develop into non-striped muscle-cells.

Intermediate Stage.

All I need say in regard to this stage is that it corresponds in every detail to the same stage in the Mole (see Plate III. fig. 8).

Active Stage.

A full-grown male was killed in July 1888. The prostate glands formed two large masses made up of tortuous tubules placed in front of the urinary bladder (see Plate II. fig. 6).

Under the microscope the same elements are seen as in the quiescent stage of the gland, but the tubules had grown and become many times larger than in that stage. The *inner* coat had to a slight degree developed longitudinal folds, and is lined by a single layer of deep columnar-shaped cells, with finely granular protoplasm, and round nuclei near their attached ends. Between their attached ends were a number of small round cells, which, as I have stated, in the case of the Mole, in all probability replace the exhausted and cast-off columnar cells. The outer coat is now composed entirely of a layer of well-formed non-striped muscle-cells. Each tubule is filled, as

in the Mole, with a mass of coagulated mucus, which contains a number of small, rounded bodies, staining deeply with carmine (see Plate III. fig. 11).

Note.—Cowper's glands undergo precisely the same changes as the prostate, both in the Mole and Hedgehog. In the latter animal the secretion from this gland during the summer is abundant, and possesses a peculiarly disagreeable and penetrating scent-like odour.

THE EFFECTS OF CASTRATION UPON THE PROSTATE GLAND.

The general effects of castration, corporal as well as mental, do not concern my purpose in this paper, and I shall therefore only refer to the effects of castration upon the Prostate and Cowperian glands. The behaviour of these accessory sexual glands after the removal of the testes will, I think, enable us to decide whether, on the one hand, they are developed in relation to the generative function, and entirely owe their existence to the generative stimulus, or, on the other hand, whether they arise independently of the testes and are essentially developed in functional relation to the urethral channel, and serve to produce a secretion which has for its purpose the moistening of that channel.

The operation of castration in various animals has been practised for many centuries, yet, so far as I have been able to ascertain, the first description of the associated changes in the generative apparatus was given by John Hunter. The following is an extract from Hunter's *Works* (vol. iv. p. 30):—

“The prostate and Cowper's glands, and those of the urethra in the perfect male [Bull], are soft and bulky, and the secretion is salt to the taste.

“In the castrated animal [Bullock] these are small, flabby, tough, and ligamentous, and have little secretion. Especially marked is the change when the animal is castrated when young.”

I have been able to confirm Hunter's observations on the generative apparatus of the Bullock, and have extended this inquiry to other domesticated animals, especially the Dog and Cat, and have also studied the histological changes which gradually supervene in the prostate after castration.

For the purposes of illustrating this subject I shall here describe a few instances in the case of the Dog and Cat and give the histological changes observed.

In the Dog.

CASE I.—A mongrel dog, aged three years, was castrated when two years old. Therefore the changes from a normal state, which in the Dog is much the same as in Man, induced in the structure of the prostate, to be immediately described, were developed in the course of one year.

The prostate was found to be small, firm, tough, and fibrous, and it presented a great contrast to the large, soft, and glandular organ in the full male Dog.

On section, a few irregular streaks of gland tubules were seen, and these were well separated from one another, and embedded in a dense fibrous stroma. The stroma seemed almost devoid of any muscular tissue.

Microscopically, the remains of the gland tubules, as seen by the naked eye, form isolated and slightly branched columns or fissures, supported and separated by a relatively large amount of stroma which consists mainly of old fibrous connective-tissue. Some of these fissures, which represent the prostate tubules, are lined by a single layer of epithelial cells, which are small, flattened, and of irregular shape, whilst others are filled by epithelial cells of much the same appearance.

The protoplasm of these epithelial cells is small in amount and clear; and it is indeed but little if at all differentiated into that kind of protoplasm which is regarded as typical of glandular and functional epithelium. This retrogression, as I venture to call it, of the normal prostatic glandular epithelium into a lower and practically functionless type is very marked, and reminds me of similar retrogressive changes in the epithelial cells of other glands under various diseased conditions—for example, in the kidney and liver.

The stroma is composed in parts of fibrous connective-tissue containing a few connective-tissue cells; and in other parts there are in addition to the connective-tissue cells some muscle fibres, which are less numerous than in the normal gland, and these are found in various stages of atrophy. The stroma forms, therefore, the main characteristic constituent in what represents the prostate after castration, whereas in the normal gland of the entire male the glandular constituent and unstriped muscular fibres form the most marked and characteristic structure (see Plate III. fig. 12).

CASE II.—A full-grown, castrated Spaniel Dog. The time at which castration was performed is unknown.

The *prostate* was found to be of small size—I judged it to be about one-third the normal size in a similar kind of dog—firm, and hard. On section it was very like fibrous tissue in which were scattered a few remnants of glandular structure. This so closely resembled the prostate of the preceding case that its description applies equally well.

Under the microscope the gland tubules are represented by slightly branching tubules which are in parts lined by a very low cubical, and in other parts by flattened, clear, epithelial cells. The epithelial cells and the stroma present the same general characters as those described in Case I.

I have been able to obtain several other examples of castrated dogs, but as they show nothing more than is above described, I need not occupy space in repeating the description.

In the Cat.

CASE III.—A five-year-old Cat, which was castrated when about three weeks old.

In the position of the *prostate* was found a small, firm, bi-lobed and unsymmetrical mass, about one-fourth the size of the normal prostate in entire male cats. A section of the mass revealed that in one-half (the largest) there still existed a small amount of gland-like tissue towards the centre. In the opposite half no glandular tissue could be detected by the naked eye. *Cowper's glands* were small, tough, and fibrous.

Under the microscope the lobule, which was observed to be devoid of any glandular structure, is found to entirely consist of old fibrous connective-tissue without any traces of prostatic gland tubules; but in the other half there is a remnant of an almost perfectly formed part of the gland, more or less occupying the centre. The tubules in this, however, have a simpler arrangement than obtain in the normal gland, and they are separated from one another by a considerable amount of connective-tissue, in which there are a few well-formed non-striated muscle-cells arranged around the extremities of the gland-tubules. The epithelial cells lining the tubules are columnar in shape, and resemble very closely those found lining the tubules of the normal prostate gland.

Cowper's Glands.—Small and fibrous. See Case IV. for description.

CASE IV.—A full-grown Cat, of unknown age, which was in all probability castrated when a few weeks old, according to the not uncommon practice.

The prostate was represented by a very small, firm, and fibrous mass. No trace of gland structure could be detected with the naked eye, on section through it. *Cowper's glands* were in a similar state, i.e., small, firm, and fibrous.

Microscopically, the remains of the prostate consist of a mass of fibrous connective-tissue containing very few muscle-cells, which are in various stages of atrophy. Embedded in this dense stroma there are small columns of degenerated epithelial cells, which once formed the glandular epithelium of the tubules.

In *Cowper's glands* the same appearances are seen; but the disappearance of the glandular structure has not advanced to such a degree as in the prostate. The tubules are slightly branched, and are in some places lined by small cubical epithelial cells, but in others

are filled with small irregular cells, forming columns similar to those seen in the prostate. The stroma of the gland is relatively very much increased, and is formed of fibrous connective-tissue.

I have also examined the generative organs of the Pig, Bullock, Sheep, and Horse after castration, and found that in each case like changes supervene.

In Man.

Although opportunities for examining the generative organs of castrated men occur not unfrequently, yet there are but few cases on record, and these cases, chiefly by German authors, have been investigated rather with respect to the general changes in the whole frame, and the degree of approach to that of the female, than to the special changes in the sexual apparatus.

Although I have not had an opportunity of examining the state of the prostate in eunuchs, yet I think it will be of interest to make here a few quotations from the reports of others.

Professor Gruber,¹ in a description of the case of a man castrated in early youth, who died at the age of sixty-five years, speaks of the prostate and utriculus masculinus in the following terms:—

“Diese [Prostata] ist sehr verkleinert. Bei angebrachten Drucke konnte ich den Liquor prostaticus an den Mündungen ihrer Ausführungsgänge hervorquellen sehen.

“Die Vesica prostatica s. Utriculus prostaticus, s. virilis, s. Uterus masculinus nach Weber ist unverhältnissmässig vergrössert, so zwar, dass das hintere Ende derselben von einige Linien den hinteren Umfang der Prostata überragte.”

Dr Bilharz, in a thesis entitled *Descriptio Anatomica Organorum Genitalium Eunuchi Æthiopis*, Berl. 1859, gives the result of the examination of two castrated men, and he confirmed the observations made by Professor Gruber.

Pelican, in a book (*Skopzenthum in Russland*, 1876, s. 99) devoted to the study of this peculiar sect in Russia, mentions that the prostates in eunuchs are about the size of that found in the child.

The above are the only observations that I have been able to

¹ Müller's *Archiv*, 1847, s. 469.

find; but these, I think, are sufficient to show that after castration the prostate in Man undergoes similar changes to those above described in the Dog. The fact that some so-called liq. prostaticus was expressed by Professor Gruber out of the remaining tubules of the prostate can be well explained by the presence of a certain amount of watery and clear fluid, not necessarily liq. prostaticus, persisting in the remnants of the ducts and tubules which remain for a considerable period, and probably never entirely disappear.

ARREST OF GROWTH OF TESTES, AND ITS EFFECTS UPON THAT OF THE PROSTATE IN MAN.

I have on more than one occasion noted the small size of the prostate gland in Dogs, when the testes were also smaller than usual; but I wish here to relate an instance of arrest of growth of the prostate in a case of arrest of growth of the genital organs. During the winter of 1888-89, Mr Willett kindly gave me an opportunity of examining a patient then under his care at St Bartholomew's Hospital, in whom the testes and external genitals had become arrested in their growth before puberty, and through the kindness of Mr Bowlby I am able to give the notes of the case.

A young married man, thirty-three years of age, suffering from *delirium tremens*. He was of medium height, flabby, beardless, and had a high-pitched voice such as is observed in eunuchs. The external genital organs, including the penis, scrotum, and testes, were only developed to the size of those of a boy between six and seven years old, and the pubes were covered by fine downy hair. On examining *per rectum* nothing more than a firmish transverse ridge could be felt in the position of the prostate gland. Micturition was normal, except during his illness, when he suffered from retention.

Another case illustrating the effect of removal of the testes upon the growth of the prostate is given by Civialé in his work¹ on diseases of the genito-urinary organs:—"Il s'est présenté, dans un hôpital de Paris, un calculeux auquel on avait pratiqué la castration de l'un et l'autre côté, pour le guérir de deux hernies. Lorsqu'on le tailla, ou reconnut que la prostate

¹ *Traité Pratique sur les Maladies des Organes genito-urinaires*, tom. ii. p. 338.

n'existait pour ainsi dire plus. On pensa que l'enlèvement des testicules avait exercé ici quelque influence."

General Summary.

It is well known that in wild animals the sexual activity recurs with a certain regularity every spring, and quickly acquires its full powers. After the acquirement of full sexual power the activity remains at its height for a time that is variable in duration in birds and some mammals; and then it gradually declines until its entire disappearance, and the sexual function is once more in abeyance compared with the nutritional and other functions of the body. This cyclical recurrence in the sexual activity or periodicity, as it may be called, is very marked in the examples of the Insectivora that I have chosen. It is accompanied by well-marked anatomical changes, which can be observed not only in the testes but also in the accessory generative glands, such as the prostate, vesiculæ seminales, and Cowper's glands, and throughout the whole of the generative apparatus. These changes are preceded by an increased vascularity of the whole tract, which determines an increased growth of all the glands and parts concerned in generation.

In the testicle the quiescent seminiferous tubules enlarge, and their lining epithelium proliferates and grows, in order to form cells, which give origin by special division of their nuclei to spermatozoa; this constitutes a return to sexual activity. In the prostate the quiescent tubules and their lining of epithelium undergo similar changes, with the exception that the epithelial cells thus formed develop into typical glandular or secreting cells, which secrete a fluid containing a large amount of mucin.

The period of sexual activity is the same in both glands, and they are dependent, or rather controlled, by the sexual stimulus, whatever the nature and course of that may be. At the end of the sexual season these glands begin to decline in activity, and then they diminish until they return to the quiescent state in which they remain for the rest of the year.

As has been shown above, the prostate in this quiescent state is composed of a few tubules lined by flattened and small epithelial cells, which are undoubtedly functionless as regards

the production of any secretion, but they possess the power of reproducing glandular epithelial cells when the appropriate time recurs. Therefore there can, I think, be no doubt that the prostate in these examples of the Insectivora, and, if in them, probably in all the mammals from the Marsupials upwards, is purely a sexual accessory gland, which produces a secretion whose sole purpose is to be incorporated with the testicular secretion and then ejected as an integral part of the seminal fluid.

Seeing, then, that the prostate is an accessory sexual gland, and acts in concert with the testes, it now remains to inquire into the manner in which the prostatic secretion, which is constantly formed during the period of activity in the rutting animals, is retained, and also by what mechanism the retained secretion is expressed into the urethra during the sexual act.

In corroboration of the view that the prostatic secretion is being constantly formed during the period of activity of the gland, is the fact that the tubules are always filled to a certain degree with secretion which coagulates by treating with alcohol, and also that the epithelial cells lining the tubules show numerous *muciginous* granules, especially in the inner or lumen half, but also, though less markedly, in the outer half of each cell.

The secretion is retained in the tubules where it is being formed, but especially is it retained in those parts of the tubules nearest to the urethra, which are usually larger. Therefore, there exists in this gland the simplest, and at the same time the most primitive, means for retaining its secretion until a demand for its expulsion into the urethra arises. The secretion thus accumulated is expelled into the urethra during the sexual act by means of the contraction which begins at the distal end of the tube, of the complete and continuous sheath of non-striated muscle that surrounds each tubule in its whole length. This sheath of muscle may be well seen in fig. 11.

The secretion is thus expelled into the prostatic—the most capacious—part of the urethra, where it mixes with the secretion from the testes and the other accessory sexual glands, before the seminal fluid proper is ejected through the urethra.

The prostate gland differs in its mode of retaining and

expelling its secretion from most other glands in the body, and it seems to me that such a muscular mechanism is made in the prostate for expelling its secretion as quickly as possible into the prostatic urethra, inasmuch as there exists no common reservoir in which the various components of the seminal fluid can be stored in a state ready for use. The existence of such a large amount of non-striped muscle in the prostate of these animals is a striking feature, and at once recalls the structure of the prostate in the higher mammals and in Man.

In my paper "On some Observations on the Anatomy of the Prostate" (*Jour. of Anat. and Phys.*, vol. xxiii. p. 374) I ventured to regard the intrinsic muscle fibres of the prostate as subservient in function to the glandular tubules, and endeavoured to show that in the developing prostate the muscle could be seen running in fine bundles in close relation to the tubules, and in such a manner as to be capable of exerting compression upon them. In the Mole there exists the simplest possible arrangement; but in Man, and indeed the Dog and Cat, the tubules have become more branched and more complex, and with this progressive evolution the muscle has been spread out on the various branches of the tubules, and has apparently lost its more intimate relation to them.

Again, after castration in the animals before mentioned (Dog, Cat, &c.), and in Man, the prostate, after the lapse of a year or more, becomes transformed into a mass of fibrous connective-tissue, which contains the remains of the once active gland-tubules, and a small number of atrophied muscle-fibres scattered here and there. The complicated and much branched prostatic tubules, together with the non-striped muscle which forms a pronounced constituent of the normal prostate, have disappeared almost entirely, leaving however some remnants both of the gland tubules lined by epithelium, which has lost its glandular or secretory function, and of the non-striped muscle-fibres.

This is the case in Dogs, Cats, Pigs, Bullocks, Horses, and in Man. Further, it has been shown above that the growth of the prostate is dependent upon the growth of the testes, and in its history follows exactly the same course as that organ; for instance, the prostate, as well as the testes, remains of small size until the time of puberty, when the generative apparatus

acquires its full development, and both glands rapidly enlarge and attain their full size. Further, in the example of arrest of growth of the testes which I have given, associated with a similar state of the whole generative apparatus, it has been pointed out that the prostate remained in a state of rudimentary development, thus corresponding with the genital glands and apparatus.

EXPLANATION OF PLATES II., III.

Figs. 1, 2, and 3, Pl. II. $\times \frac{2}{3}$.—Views from the front of the generative organs of the Mole (*Talpa europ.*), which were removed (1) in the middle of December, (2) in the middle of February, and (3) in the middle of March. These show the gradual development of the generative glands from the *resting* to the *active* stage. *a*, prostate gland; *b*, testes; *c*, urinary bladder; *d*, penis; *e*, rectum; *f*, membranous part of urethra covered by the well-developed *constrictor urethra*.

Figs. 4, 5, and 6, $\times \frac{2}{3}$.—Similar views of the generative organs of the Hedgehog (*Erinaceus europ.*)—(4) in the middle of winter, (5) in April, and (6) in the summer. The letters indicate the same structures as in figs. 1, 2, and 3. *g*, kidneys; *h*, seminal vesicles.

Fig. 7, Pl. III. $\times 80$.—Transverse sections of two tubules from the prostate gland of the Mole in the *resting* stage, showing the small size of the tubules, which are lined by (*a*) very low cubical epithelium, and surrounded by (*b*) a thick layer of large spindle-shaped cells, representing the muscular sheath.

Fig. 8, $\times 80$.—Transverse sections of two tubules from the prostate gland of the Mole in the *intermediate* stage, showing a considerable increase in the size of the tubules. The lining is now convoluted, and is covered internally by low columnar epithelial cells (*a*), and externally by a well-developed ring of non-striped muscles (*b*).

Fig. 9, $\times 80$.—Transverse section of a tubule of the prostate gland of the Mole in the stage of *activity*, showing an enormous increase in size of the tubule; the subdivision of the folds covered by columnar epithelium, and the coagulated secretion, containing many small round cells, in the lumen. The muscle forms a well-marked ring around the tubule. *a*, columnar epithelium; *b*, ring of non-striped muscle; *c*, coagulated secretion.

Fig. 10, $\times 80$.—(A) Transverse section of a tubule of the prostate gland of the Hedgehog during the *resting* stage, showing precisely the same structures as are seen in fig. 7. (B) Longitudinal section of a tubule from the same prostate, showing the way in which they branch and also the continuous sheath of non-striped muscle fibres.

Fig. 11, $\times 80$.—Transverse section of the tubules of the prostate gland of the Hedgehog during the *active* stage, showing the great

increase in the size of each tubule. The convoluted lining is covered by well-developed columnar epithelium. The lumen is partially filled with coagulated secretion. Each tubule is surrounded by a well-marked ring of non-striped muscle-fibres. *a*, epithelium; *b*, muscle-ring; *c*, loose intertubular connective-tissue.

Fig. 12, $\times 80$.—A section taken from the periphery of the prostate gland of a Spaniel Dog which had been castrated (see Case II.). It shows that the gland has been almost entirely converted into fibrous connective-tissue, in which there are seen a few branching fissures lined by flattened epithelium. These represent the original gland tubules; and there are only traces of atrophied muscle-fibres. *a*, altered gland tubules; *b*, connective-tissue stroma.

THE VERTEBRAL COLUMN OF A YOUNG GORILLA.

By JOHNSON SYMINGTON, M.D., F.R.S.E., *Lecturer on Anatomy, School of Medicine, Edinburgh.* (PLATE IV.)

THE spine I propose to describe in this paper belonged to a male Gorilla. This animal was 24 inches high, measured from the top of the head to the sole of the heel, the hip- and knee-joints being extended as fully as possible without the use of more than a slight amount of force. All its milk teeth had erupted, but none of the permanent set. Its age was probably about two years. It came into my possession in a good state of preservation; but the thoracic and abdominal viscera had been removed by an anterior median incision, which passed through the anterior abdominal wall and the lower part of the thoracic wall. The ribs and the greater part of the sternum were intact, and the pelvic viscera still *in situ*.

As the nature of the spinal curvature in the Gorilla has not been thoroughly settled, I thought it would be well to investigate its condition in this specimen. Although the thoracic and abdominal viscera had been removed, it still appeared to me to be available for the determination of the normal curvature of the spine, since Professor D. J. Cunningham¹ found that the removal of these organs, and also the sternum and costal cartilages, did not appreciably affect the curves of the human spine, and we may fairly conclude that this would hold good also for the anthropoid Apes.

The method employed was similar to that adopted by Cunningham in his investigations on the lumbar curve in Man and in the Apes, and by myself when engaged in the study of the topographical anatomy of the Child, viz., the animal was laid upon its back, and after being thoroughly frozen in this position it was divided in the mesial plane with a saw, and careful tracings taken of the two cut surfaces before they were allowed to thaw. The sections of the spine made in this way were very

¹ "The Lumbar Curve in Man and the Apes," *Cunningham Memoir*, No. 2, Royal Irish Academy, 1886, p. 46.

successful. In the head and upper part of the neck the saw deviated very slightly to the left, but in the lower half of the spine it was almost exactly in the mesial plane, so that in each lateral half parts of all the coccygeal vertebræ were exposed.

The vertebral formula in the Gorilla, according to Flower's *Osteology of the Mammalia*, 3rd ed., 1885, is $C_7, D_{13}, L_4, S_6, C_4$. The total number of vertebræ, viz., thirty-three, is the same in this specimen as that given by Flower. In the cervical region there are, as usual, seven vertebræ. The centre for the odontoid process of the axis has not yet commenced to unite with the one for the body, but the spinous processes of the five lower cervical vertebræ are already relatively very long. Below the cervical part of the spine there are thirteen rib-bearing vertebræ. The lumbar vertebræ are generally described as four in number, but from an examination of the section it might be supposed that there were only three in this case; since while the intervertebral disc immediately below the 3rd lumbar is well developed, the next disc lower down is scarcely 2 mm. in thickness. Again, the body of the vertebra between these two discs has the shape of an ordinary 1st sacral rather than a last lumbar, for it is longer than any of the lumbar, and its diameter from before backwards is distinctly greater at its upper than its lower border. On one half of the spine a transverse section was made through this vertebra, and in the anterior part of its lateral mass there was found an ossific centre quite distinct from those for the body and neural arch. The lateral aspect of the bone external to this nucleus formed the upper and anterior part of the auricular surface for articulation with the ilium. It was therefore obvious that this vertebra presented in its shape, ossification, and relations to the ilium the characters of a typical first sacral. It however occupied that position in the series which is generally regarded as the last lumbar, so that it might be looked upon as a lumbar vertebra which had acquired sacral characters.

In the human subject there are normally twenty-four true or pre-sacral vertebræ, the 25th of the series counting from above downwards being the 1st true sacral. The total number of true vertebræ is the same in the Gorilla; but the vertebra in this animal corresponding to the 1st lumbar in the human subject

carries a pair of ribs, so that it is described as having thirteen dorsal and four lumbar vertebræ. The 4th lumbar in the Gorilla is therefore homologous with the 5th in Man. A modification of this vertebra, by which it acquires more or less of a sacral character, is not very uncommon in the human subject, but is by no means of such frequent occurrence as in the Gorilla. This fact was noticed by Professor Owen as far back as 1853, for at that time he wrote as follows:—"The tendency to a sacral modification of the transverse processes of the last lumbar vertebræ is more constant and more marked in the Gorilla than in Man; this at least is the result of an examination of four adult skeletons—two male and two female—which have now reached Europe."¹ Two out of these four skeletons exhibited this tendency. In order to ascertain its frequency in a larger number of specimens, I have examined the spines of twenty-six Gorillas,² and found that in eighteen of them the last lumbar, or the 24th of the series, displays more or less completely sacral characters. The degree of sacral modification varied considerably in the different specimens, but in all of them it was indicated by its transverse portion being thickened, articulated externally with the ilium, and joined behind to the lateral mass of the 1st sacral. According to Cunningham,³ a sacral modification of the last lumbar is extremely common in the Chimpanzee. Unfortunately, our knowledge of the ossification of the last lumbar vertebra in these cases is very defective. Of the eighteen examples of Gorilla's spines already referred to, in which the last lumbar presented sacral modifications, fifteen were adults,

¹ "Osteological Contributions to the Natural History of the Chimpanzees (Troglodytes) and Orangs (Pithecus). No. 5. Comparison of the Lower Jaw and Vertebral Column of the Troglodytes Gorilla, *T. Niger*, *Pithecus satyrus*, and different varieties of the Human Race," *Trans. Zool. Soc. of Lond.*, vol. iv. p. 104.

² Of these twenty-six spines, ten are in the Natural History Department of the British Museum at South Kensington; seven in the Museum of the Royal College of Surgeons of England; one in the Museum of Comparative Anatomy at University College, London; two in the Edinburgh Museum of Science and Art; one in the Anatomical Museum, University of Edinburgh; three in the Science and Art Department, South Kensington; and one in the Owens College Museum, Manchester. I have to thank the gentlemen in charge of these collections for their kindness in affording me every facility for examining the specimens.

³ "The Spinal Curvature in an Aboriginal Australian," Abstract in *Proc. Roy. Soc. of Lond.*, read January 14, 1889.

and therefore were not available for the determination of the ossific centres. The remaining three specimens belonged to young animals. In one of these, kindly lent me by Professor Howes, there were remains of a suture indicative of the presence of a centre for the anterior part of the right transverse process, but the suture could not be made out on the left side. In this specimen the vertebral column was about 2 inches longer than in mine, so that it was probably a little older.

In another, which is in the Natural History Department of the British Museum at South Kensington, there are no indications on the surface of the bone of any epiphysial line. In my own specimen I made transverse sections through the 4th lumbar and the 1st and 2nd sacral vertebræ, and found a separate centre in the anterior part of the lateral process of the last lumbar, and also one in the 1st sacral, but could not detect one in the 2nd sacral. The centre in the 4th lumbar was connected internally with the body, and behind with the posterior part of the transverse process of the vertebra by a layer of cartilage less than a millimetre in thickness.

Although mine was the only specimen in which I had an opportunity of actually demonstrating the presence of a typical pleurapophysial element in the anterior part of the transverse process of the last lumbar, still from the degree of development of the lateral portion of this bone in several other cases, I have no doubt that their mode of ossification was similar to that of mine. We must therefore admit that the 24th vertebra, counting from before backwards, of the Gorilla may present the typical appearances of an ordinary lumbar vertebra, but that in the majority of cases its transverse process becomes enlarged and joins the ilium and the lateral mass of the 1st sacral, and that this sacral modification may result in the development of a distinct centre uniting its body with that of the ilium. These facts are of special interest in connection with the homologies of the vertebræ in the anthropoid Apes, and they appear to me to favour the views of Rosenberg¹ rather than those of Welcker² and Holl.³

¹ "Ueber die Entwicklung der Wirbelsäule," *Morph. Jahrbuch*, bd. i.

² "Ueber Wirbelsäule und Becken," *Arch. f. Anat.*, 1881.

³ "Ueber die richtige Deutung der Querfortsätze der Lendenwirbel und die Entwicklung der Wirbelsäule des Menschen," *Sitzungsab. der k. Akad. der Wien.*, iii. Abth., 1882.

The Gorilla and Chimpanzee are generally described as having seventeen dorso-lumbar vertebræ, while in the Orang there are only sixteen, and in the Gibbons eighteen. According to Rosenberg, the 1st sacral, or the 25th of the series, in the Gorilla and Chimpanzee is homologous with the last lumbar in the Gibbon, and the 2nd sacral in the Orang. Welcher and Holl, on the other hand, consider that the 1st sacral or "stutzwirbel" of one animal is homologous with the 1st sacral of any other animal. The existence of "übergangswirbeln," both in the dorso-lumbar and lumbo-sacral regions, favours a serial homology of all the vertebræ, rather than the homology of the vertebræ of one region with those of the same region in another animal, independent of the total number of vertebræ.

The observations of Holl regarding the development of the lumbar and sacral vertebræ throw light upon the formation of lumbo-sacral modifications. He found that transverse sections through the 1st lumbar and the 1st sacral vertebræ in a human embryo with a vertebral column 28 mm. in length showed a very close resemblance in general form between these two vertebræ, and indeed they can only be distinguished by the presence of the ilium at the side of the 1st sacral. This similarity between the two he found to still exist in two embryos with spines 28 mm. and 42 mm. respectively long, the lateral processes of the two vertebræ occupying similar positions. A little later in foetal life, however, the transverse process of the lumbar vertebra appears to undergo a considerable change. Thus in an embryo with a column 52 mm. in length, it had lost its primitive transverse direction at the side of the body, being inclined outwards and backwards, and lying nearer the dorsal aspect. Somewhat later in foetal life, a centre appears in the anterior part of the lateral process of the 1st sacral, while there are no indications of a corresponding centre in the lumbar.

In those cases in which the last lumbar possesses the characters of a 1st sacral, we may fairly conclude that the ilium becomes connected with its transverse process while it retains its embryonic form. This union prevents the atrophy of the anterior portion of the lateral process of the lumbar vertebra, and the subsequent appearance of an ossific centre may be regarded as a convenience of growth, or as an indication of a tendency to

the formation of pleurapophysial elements in connection with the lumbar vertebræ.

D. J. Cunningham¹ has recently directed attention to the fact that in the Chimpanzee the cartilaginous disc between the last lumbar and 1st sacral may be very thin. This is also very marked in my section of the Gorilla. This change in the thickness of the lumbo-sacral disc seems to be of a secondary nature. The union of the last lumbar with the ilium must interfere with the normal movements at the lumbo-sacral articulations, and consequently the cartilaginous disc between their bodies will tend to disappear. I believe its thickness will be found to vary inversely with the degree of fixation of the last lumbar. In my specimen the articulation of the vertebra with the ilium is very extensive, and the disc below its body is about the same thickness as the discs between the bodies of the true sacral vertebræ.

The coccygeal vertebræ are four in number, both in Man and the Gorilla, but the last two pieces differ greatly in their period of ossification. Thus in my Gorilla the bodies of all the coccygeal vertebræ are well ossified, and Deniker² found this to be the case even in a foetal Gorilla of about the sixth month. In the human subject the 3rd and 4th coccygeal vertebræ remain in a cartilaginous condition until puberty. It is difficult to afford a satisfactory explanation of this difference, but its tardy ossification in the human subject, as compared with the Gorilla, may be regarded as an indication that the coccyx is less developed in the former than in the latter.

Curvature of the Spine.—The main questions connected with the spinal curvature in the Gorilla is whether or not there is an anterior convexity in the lumbar region, and, if it be present, the time and extent of its development.

Sir Richard Owen, in a paper which he read before the Zoological Society of London in 1851, stated that "the vertebral column of the Gorilla differs from that of Man in showing but one gentle curve, with the concavity forwards, from the sacrum to the cervical series, which series is straight when extended"

¹ "The Spinal Curvature of an Aboriginal Australian," *Proc. Roy. Soc. Lond.*, vol. xlv. p. 494.

² *Recherches sur les singes anthropoides*, Paris, 1886, p. 81.

(p. 93). This opinion appears to have been based merely upon the examination of the macerated vertebræ, yet numerous authorities have supported his views. Aeby,¹ indeed, not only denies the existence of a lumbar curve in the Gorilla, but also specially maintains that the shape of the bodies of the vertebræ in any animal permits us to draw conclusions as to the direction of the spinal curves. He found from measurements of the bones of the Gorilla that the depth of the bodies, from the 6th cervical to the last lumbar, was less in front than behind, while in Man this anterior wedge-like diminution only extends from the 5th cervical to the 2nd lumbar. He accordingly concludes, that a lumbar curve does not exist in the Gorilla.

D. J. Cunningham, however in his elaborate researches on "The Lumbar curve in Man and the Apes" (*Cunningham Memoirs*, Royal Irish Academy, 1886), has conclusively demonstrated that the theory upon which Aeby based his conclusions is an erroneous one, and that "the intervertebral discs alone are quite sufficient of themselves to build up a lumbar convexity, even in cases where the vertebral bodies are shaped in a fashion antagonistic to the curve" (p. 85). This was well shown by Cunningham in the Chimpanzee, for while he found the lumbar vertebræ in this animal to be even less adapted by their form for the production of an anterior lumbar convexity than those of the Gorilla, yet frozen sections of the fresh spines of several Chimpanzees demonstrated the existence of a well-marked lumbar convexity. Cunningham expressed his belief that the lumbar curve was well developed in the Gorilla, although he had not an opportunity of verifying his conclusions from a section of a fresh spine. The specimen I have prepared, however, amply confirms that opinion. The method adopted in the examination of this spine has already been described; but there is one additional point that must be mentioned, since inattention to it might invalidate the whole results. In 1863 Professor Cleland² demonstrated upon a new-born child that the curvature of the lumbar portion of the spine was greatly influenced by the posi-

¹ "Beiträge zur Osteologie des Gorilla," *Morph. Jahrb.*, bd. iv.

² "Tracings of a Mesial Section of a New-born Child," *Report of the British Association for the Advancement of Science*, 1863.

tion of the thighs, the forward convexity being obliterated by acute flexion, and rendered very prominent by complete extension. There is no doubt but that in the Gorilla, in which the extension of the thigh at the hip-joint is less complete than in the new-born subject, any attempt to forcibly extend the thighs would give rise to a lumbar curve. To avoid any production of a curve from this cause, my specimen was frozen with its thighs flexed upon the trunk, so that they formed rather less than a right angle with it. A glance at the section of the spine shows that it possesses, as in the human subject, four curves, the anterior surface being convex from above downwards in the cervical and lumbar regions, and concave in the dorsal and sacral. The dorsal cavity is well developed, while that of the sacral is only feebly marked. The most convenient method of estimating the degree of curvature in the lumbar region is that employed by Cunningham. He draws a straight line from the centre of the upper border of the 1st lumbar to a corresponding point on the lower border of the 5th lumbar. The distance of the most prominent point on the anterior surface of the spine from this line, multiplied by 100 and divided by the length of the line, gives the *index of the lumbar curve*. Calculated in this way, Cunningham found the average index in seven males to be 8·8, and in five females 9·5. In animals in which the lumbar vertebræ were more or fewer than five, he measured the last five true vertebræ. Thus, in the Chimpanzee he included in the lumbar region the 13th dorsal as well as the four lumbar. He found that in four of these animals, one male and three females, the average index was 8·7, or practically the same as that in seven adult male human spines. In one of the Chimpanzees, the youngest female, the index was 10·0. Measuring my Gorilla's spine in the same way, I find that it gives an index of no less than 12·3; so that it goes to prove that the lumbar curve is even better marked in the Gorilla than in the Chimpanzee. It must be remembered that this index is based upon a measurement which includes the last lumbar, and I have already described this bone as having undergone a sacral modification. Cunningham gives illustrations of mesial sections of the spines of three of his Chimpanzees. In one (see plate vii.) the lumbo-sacral disc is nearly as thick as the disc between the last two

lumbar vertebræ, while in the other two (see plate iii, females No. 1 and No. 2) it is evidently much thinner. The diminution in the thickness of the lumbo-sacral discs in the two females may be taken as an indication that in them the last lumbar vertebræ has undergone some sacral modification. This seems to increase the index of the lumbar curve, for in these two females it is 8·7 and 10·0, while in the other specimen it was only 7·1.

According to my observations, the lumbar curve is developed at a much earlier period in the Gorilla than in the human subject. Thus, in a medial section¹ of a boy about six years old, the lumbar curve was but feebly marked, its index being only 4·1; while even in a similar section² of a girl aged thirteen years the index of the lumbar curve was only 6·4, or little more than half that of my Gorilla. As all Cunningham's Chimpanzees were young animals, the Chimpanzee and Gorilla resemble one another in the early development of the lumbar curve. They also agree in the absence of a promontory.

Professor Huxley is one of the few anatomists who have recognised the existence of a lumbar curve, and even he considered that it was less marked than in Man. Thus, in *Man's Place in Nature*, published in 1863, he wrote as follows:—"The vertebral column of the Gorilla, as a whole, differs from that of Man in the less marked character of its curves, especially in the slighter convexity of the lumbar region. Nevertheless the curves are present, and are quite obvious in the young skeletons of the Gorilla and Chimpanzee which have been prepared without the removal of the ligaments." As the lumbar curve in the Gorilla is entirely dependent upon the shape of the intervertebral discs, its spine, dried with the discs in position, will naturally show a less marked curve than a fresh specimen. Through the kindness of Dr Traquair, I had an opportunity of examining the skeleton of a young adult female Gorilla, in which the spine had been prepared without the removal of the discs. It had a lumbar convexity which, on careful measurement by Cunningham's method, gave an index curve of 6·0. There is a similar specimen of an adult male Gorilla recently added to the Anatomical

¹ *The Topographical Anatomy of the Child*, plate ii.

² *Ibid.*, plate ii.

Museum of the Edinburgh University by Sir Wm. Turner, which also shows a distinct lumbar curve. It therefore appears that this curve is well marked in the adult as well as in the young animal. We are unable, however, at present to determine the precise degree of the curve.

EXPLANATION OF PLATE IV.

Fig. 1. Right half of vertical mesial section of the vertebral column of a young Gorilla, from the 12th dorsal vertebra downwards to the last coccygeal vertebra, and of the pubic symphysis. Life size.

Fig. 2. Left half of vertical mesial-section of the same animal. It shows the position of the thigh when the animal was frozen, and the section made. Reduced by photography.

FURTHER OBSERVATIONS ON THE INNERVATION
OF AXILLARY MUSCLES IN MAN. By J. T. WILSON,
M.B. Edin., *Demonstrator of Anatomy in the University
of Sydney, New South Wales.*

IN the issue of this *Journal* for January 1888, I recorded the results of a dissection of axillary muscular arches on both sides of a subject, in which I was successful in tracing their nerve-supply. As I then stated, I had at that time found no note of any previous observation on the innervation of these slips amongst the rather numerous published references to their occurrence. But at the close of a paper on the sternalis muscle, in the succeeding issue of the *Journal*, Professor Cunningham refers to two cases which had come under his observation, and which he had described in an unpublished paper read at the meeting of the British Association at Montreal in 1884. Again, in a recent paper on the subject in this *Journal* (Jan. 1889), Professor Ambrose Birmingham refers to a similar case recorded by Karl Bardeleben in the *Jenaische Zeitschrift* (Bd. xv. N.F. viii., 1881), which had escaped my notice, and which, so far, appears to have been at that time the only actually published case. In the paper referred to Professor Birmingham records, in addition, two cases which had come under his own observation, along with two noted by Dr St John Brooks. He thus collects in all nine instances (reckoning the sides of the body separately) in which the nerve-supply of achselbogen has been determined.

I have lately examined five subjects, furnishing seven additional cases of achselbogen, and in five of these I traced the nerve-supply. In the following accounts of various observations I have entered with some detail into the accompanying arrangements of nerves more or less intimately related to the nerve of supply to the muscle. I consider detail of this kind of some importance, for from such data broader conclusions are possible than from a record of merely isolated facts.

Three of the subjects examined were dissected by me in the *post-mortem* theatre of the Prince Alfred Hospital here. Owing

to this circumstance, the dissections, though extremely satisfactory so far, were not so complete as I could have wished. The first body was that of an English sailor, æt. 48. The body was emaciated, and on abducting the arms tense bands were seen and felt crossing the two axillæ. On the left side a well-developed muscular achselbogen was found in its usual position, and presented the ordinary connections and relations. A slender nerve entered this slip about its middle, and this, being followed upwards under cover of the pectoralis minor, was seen to spring from a large branch of the internal anterior thoracic nerve, which was directed downwards under cover of the pectoralis minor, and then observed to enter the lower border of the pectoralis major supplying it. The internal anterior thoracic nerve was large, and, in addition to the above-named branch, gave off the usual branches to the pectoralis minor, one of which pierced the muscle to enter the pectoralis major. The external anterior thoracic nerve gave off two large branches, which formed loops of communication across the artery with the internal anterior thoracic, but its branches of distribution appeared considerably smaller than usual. The intercosto-humeral nerve was very large, and crossed the axilla under cover of the muscular arch. It communicated twice with the nerve of Wrisberg.

On the right side the achselbogen was larger than on the left, being about the size of an ordinary omohyoid muscle. It had the usual origin from the anterior border of the latissimus dorsi, and its fleshy fibres were separated from those of the latter muscle by an oblique tendinous intersection. Into the latissimus aspect of the intersection certain muscular fibres were inserted, which seemed at first sight to be simply those of the anterior border of the latissimus, but which were found to consist of a series of fibres converging to this insertion from their origin from the fascia covering the serratus magnus, where they formed a sparse layer extending as far forwards as the mid-axillary line. At their insertion into the tendinous intersection, as above, their course formed an angle with that of the fibres of the achselbogen, and there was no continuity between the muscular fibres on either side of the intersection.

Two slender nerve-filaments were discovered supplying the

fleshy belly of this achselbogen. These were traced upwards, and found to come off, along with a small twig to the pectoralis major, from a plexiform arrangement of branches of the external and internal thoracic nerves placed between the pectoralis major and minor. To reach this some branches of the internal anterior thoracic nerve turned forwards over the upper border of the pectoralis minor. Time did not admit of the complete dissection of this anterior thoracic plexus, but the branch from which the axillary muscle was innervated was traced, and its fibres found to come entirely or chiefly from the internal thoracic nerve. Other branches from this plexus were distributed to both pectorals, and one branch supplied to the pectoralis major was directed downwards on its deep surface, and, after giving branches to the muscle, pierced its lower border to become cutaneous, supplying the skin over the anterior fold of the axilla. This branch also was traced up, and found to derive its fibres chiefly, if not wholly, from the internal anterior thoracic nerve; and it appeared to correspond to the large branch on the opposite side of the body from which the twig to the axillary muscle was derived. The chief difference consisted in its being directed on this (the right) side between the pectorals, while on the other side it passed down under cover of the pectoralis minor. The intercosto-humeral nerve was much smaller on this than on the opposite side, while the nerve of Wrisberg was slightly larger than its fellow. The intercosto-humeral nerve here pierced the axillary muscle, but supplied no branch to it.

Further dissection showed that on both sides of this subject the first dorsal nerve was reinforced by a large contribution from the second dorsal nerve. On each side of the body the nerve of Wrisberg and the internal anterior thoracic nerve were traced to their origins from the brachial plexus by two roots, each from the eighth cervical and first dorsal nerves respectively; but there was no evident union between the nerves in question or their roots, other than their origin from the same spinal nerves.

This curious arrangement between the pectoral muscles, which I have just called an *anterior thoracic plexus*, is probably to be regarded as merely an amplification of the ordinary loop or loops of communication (which were otherwise absent) between the

two anterior thoracic nerves. But the ansal arrangement must further be regarded as having been pulled forwards and downwards over the upper border of the pectoralis minor, so that its elements were superficial to that muscle instead of beneath it; and, further, the original simplicity of the looped arrangement had been lost. The cutaneous branch which pierced the lower part of the pectoralis major to supply the skin of the anterior fold of the axilla, is also a very unusual anomaly of distribution, although it is not so uncommon to find cutaneous filaments of one of the anterior thoracic nerves distributed to the skin over the region of the mamma.¹ But the variety just noted is worthy of special remark, because it shows one of the thoracic nerves (probably the internal) conveying cutaneous fibres which usually are transmitted through one of the lateral cutaneous branches of the upper intercostal nerves, usually the third, but sometimes through the intercosto-humeral.

In his recent paper on the subject Professor Birmingham has shown, by reference to data collected by him, that the modes of innervation of achselbogen, described by the present writer in a former paper, do not represent the prevailing type of the nerve-supply of these slips. But, as apparently anomalous cases, they are of very considerable interest and importance. Professor Birmingham has indeed furnished an exceedingly plausible reconciliation with the usual type, of one of these unusual modes, that, namely, in which the axillary slip was supplied by a branch from the nerve of Wrisberg. His interpretation involves a view as to the homology of the "lateral cutaneous nerve of the thorax," in animals, which I was by no means unprepared for when I wrote my paper. Such a possible interpretation is, indeed, indicated at the close of that paper in the following words in reference to the pectoralis quartus:—

"But when we remember the relation of the 'lateral cutaneous nerve of the thorax' to the external anterior thoracic nerve, a distinct communication invariably existing between them, and the fact that in the Opossum there is no internal anterior thoracic nerve as such, we must decide to suspend judgment until a special inquiry into the homology of this muscle has been made."

¹ Krause, *Varietäten*, Dritte Auflage, p. 206.

Such an inquiry has been made by Professor Birmingham, the general result of which tends to negative the idea of the homology of the pectoralis quartus to the panniculus, and to affiliate it rather to the pectoral group, while the further result of the inquiry has been to establish a theory of the compound character of the "lateral cutaneous nerve of the thorax," through morphological comparison of its nature and constitution in a series of mammalian forms. Thus the complete fusion of internal anterior thoracic and nerve-of-Wrisberg elements, is seen in the Opossum, &c., and its converse,—complete distinction of the two elements,—in Man. And thus in cases of achselbogen possessing the usual nerve-supply from the internal anterior thoracic, the intervening twig is the real representative of the motor part of the "lateral cutaneous nerve of the thorax," which, as such, has long since disappeared, leaving behind it only its sensory fibres, as nerve of Wrisberg. And this view, as Professor Birmingham points out, renders quite intelligible the fact of an occasional innervation of the achselbogen from the nerve of Wrisberg, such as was described by me. But he seems to regard as quite inexplicable the condition observed on the other side of the body, where the axillary muscle was supplied by the intercosto-humeral nerve, for he shortly disposes of it as an abnormality. But abnormalities are often enough of great value, just because they not infrequently indicate more obscure relationships which might easily be ignored. And that the abnormality in question is not unique is shown by the records of the two following cases, both of which have come under my observation since this paper was begun.

The first subject was a female, æt. 52, and was dissected in the *post-mortem* theatre, Prince Alfred Hospital. The axillary muscle was present on one side only, and was innervated by two minute filaments from the intercosto-humeral nerve entering its inner surface. Very careful dissection failed to discover any other nerve-supply to the muscle, which was a small one. The nerve of Wrisberg was a small twig and joined a branch of the relatively large intercosto-humeral nerve, distal to the nerve for the achselbogen. The anterior thoracic nerves showed no noteworthy deviation from their usual distribution.

Here, then, as in my former case, there was no room for doubt as to the proximate source of the nerve of supply. It is not possible that the minute and probably sensory filament, which Professor Birmingham found in one of his cases entering the muscle from the intercosto-humeral, represented a possible *path* for motor filaments, and one which is actually traversed by them in such instances as I have described? The affirmative answer to this question receives the strongest confirmation from a consideration of the details of the next case which I have here to record, and which I examined very recently in the *post-mortem* theatre, Prince Alfred Hospital. The subject was a female, æt. 29, and an achselbogen was present in the right axilla. The intercosto-humeral nerve was large, and crossed the axilla in two large branches. The more anterior of these pierced the fibres of the achselbogen to reach the arm, but before doing so it was observed to furnish a fair-sized branch of supply, which entered and terminated in the muscle. No other nerve entered the muscle.

The more posterior of the two branches of the intercosto-humeral also crossed the axilla to reach the inner aspect of the arm, and while in the axilla it formed a considerable loop of communication with the nerve of Wrisberg, which was also of a fair size. But when the anterior branch of the intercosto-humeral was traced inwards towards its point of exit from the second intercostal space, it was found to be joined at about an inch from the chest-wall by a fine nerve, which was followed upwards in the axilla under cover of the pectoralis minor to its origin from a large branch of the internal anterior thoracic nerve. This large branch, being traced in turn, was found to derive fibres from each of two roots by which the internal anterior thoracic nerve arose from the brachial plexus, one of them being conjoint with the origin of the nerve of Wrisberg and springing from the cord formed by the eighth cervical and first dorsal nerves. These facts have important bearings on the question at issue, and I think that there can be no reasonable doubt that the twig of supply from the intercosto-humeral to the achselbogen in this case consisted of the very same fibres as entered that nerve through the communicating twig from the internal anterior thoracic nerve, and if so, the fact is thus

established that the intercosto-humeral nerve does occasionally form a path, so to speak, for the motor fibres to the achselbogen.

Now, when the fact of the occurrence of such a condition is admitted, it may be contended that a *peripheral* transference of fibres from one path to another, such as is instanced above, is quite easily intelligible, and that it probably affords a true explanation of the cases of apparent supply by genuine fibres of the intercosto-humeral nerve itself. But in these latter cases very careful dissection revealed no such communication between the anterior thoracic and the intercosto-humeral; and the only reason known to me for assuming that the motor fibres from the second dorsal nerve do not possess the same alternative paths, along intercostal nerve and brachial plexus respectively, which are freely granted to sensory fibres of the same spinal nerve-root, is, that experiments on animals do not tend to show that the intercosto-humeral contains motor fibres for the panniculus. Against such a preliminary assumption I cite the admitted fact of the interchangeability of route of *sensory* fibres of the second dorsal nerve, which may either pass up to the brachial plexus and thence through the nerve of Wrisberg to the arm, or may traverse the second intercostal space and gain the axilla in the intercosto-humeral. And, again, it is probable that the fibres of the internal anterior thoracic nerve, which I have described above as in one case becoming cutaneous over the anterior fold of the axilla, were really fibres from the second dorsal nerve-root, whose not infrequent path is the intercosto-humeral nerve (*cf.* Ellis's plates). I have found in more than one dissection that the branch of the internal anterior thoracic nerve, supplying an axillary muscular arch, was traceable to the lowest root of the brachial plexus, *i.e.*, to the root which receives the contribution from the second dorsal nerve, and I think, when we consider the different varieties of nerve-supply of achselbogen, that it becomes extremely probable that this structure is to be localised in the second dorsal nerve-muscle segment. Thus we would regard the nerve fibres supplying it as choosing one of two primary routes—either (and more commonly) through the ascending branch to the first dorsal nerve and brachial plexus, or (more rarely) along with the intercostal nerve and its inter-

costo-humeral branch. In the first case a further choice is to be regarded as open: either the fibres in question may (as they generally do) pass along with other motor fibres in the internal anterior thoracic nerve, or they may be dissociated from other motor fibres, and may accompany those sensory fibres from the same segment, forming the nerve of Wrisberg; or, indeed, a third probability is illustrated by the case recorded above, in which the fibres dissociate themselves *in the axilla* from the internal anterior thoracic nerve and associate themselves with the intercosto-humeral nerve.

Professor Birmingham is doubtless right in regarding the innervation of achselbogen from the internal anterior thoracic nerve as the rule, as it occurred in five cases out of the nine collected by him, and since three other cases were reconcilable with such a rule; but I believe that he is mistaken in regarding the remaining case recorded by me as an "abnormality," if by that term he means that it is absolutely irreconcilable with the normal arrangement. That it is not so rare as he supposes is evident from the appended table, which shows that, were I to be guided by my own statistics alone, I should be in doubt as to which was the most common arrangement.

Table of Observations on the Innervation of Axillary Muscular Arches in Man.

Observer.	Reference.	Nerve Supply.
1. Bardeleben, .	<i>Jenaische Zeitschrift</i> , Bd. xv., 1881,	Int. ant. thor. nerve.
2. Wilson, .	<i>Jour. Anat. and Phys.</i> , Jan. 1888,	Nerve of Wrisberg.
3. " .	" " "	Intercosto-humeral nerve.
4. Cunningham,	<i>Jour. Anat. and Phys.</i> , March 1888,	Int. ant. thor. nerve.
5. " .	" " "	" "
6. Brooks, .	<i>Jour. Anat. and Phys.</i> , Jan. 1889,	" "
7. " .	" " "	Loop bet. ant. thor. nerves.
8. Birmingham,	" " "	Int. cord of plexus between int. ant. thor. and nerve of Wrisberg.
9. " .	" " "	Int. ant. thor. (and intercosto- humeral. Sensory?).
10. Wilson, .	" "	Int. ant. thor. nerve.
11. " .	" "	"Anterior thoracic plexus," really fr. int. ant. thor.
12. " .	New Cases,	Intercosto-humeral.
13. " .	" "	" "
14. " .	" "	Int. ant. thor. nerve.

In conclusion, then, it must be admitted that the innervation of axillary muscular arches from the internal anterior thoracic nerve is the normal, in the sense of being numerically the most frequent arrangement; but I think it highly probable that the determination of the muscle, as somehow related to the second dorsal nerve-muscle segment, will be our real guide in the interpretation of the diverse varieties of its innervation which have been observed.

Addendum.—Since the foregoing paper was sent off for publication I have dissected another subject (female, æt. 25) in whose left axilla an achselbogen was present. It was innervated by a long slender branch of the internal anterior thoracic nerve passing downwards from under cover of the pectoralis minor muscle.

THE SIGNIFICANCE OF THE THIRD TROCHANTER AND OF SIMILAR BONY PROCESSES IN MAN.

By THOMAS DWIGHT, M.D., LL.D., *Parkman Professor
of Anatomy at Harvard University.*

IN a very interesting paper on the "Effect of Strain on Bones, Muscles, and Ligaments," read at the meeting of the British Medical Association at Glasgow, in August 1888, by Mr W. Arbuthnot Lane,¹ the author took, as a text for refutation, some remarks from a paper of mine on the "Human Shoulder Blade."² Such criticism, especially when made in so friendly a spirit, is very profitable, and I am glad to avail myself of an opportunity of replying before as nearly as possible the same audience. I should, however, have replied sooner had I not been prevented, first by more urgent duties, and later by necessary idleness. The following is the essential part of Mr Lane's allusion to myself:—

"He goes on to mention the usual slight projection from the axillary margin of this bone (the human scapula), which is occasionally very largely developed. He says that this process bears no direct ratio to the size of the *teres major*, and that the third trochanter on the femur is an analogous case, the occurrence of which, in his opinion, is quite uninfluenced by muscular development; also, that its existence in man is probably, as in the case of the third trochanter, the appearance of a peculiarity of a lower form. . . . In reference to the two conditions to which he calls attention, namely, the projection from the axillary border of the scapula and the third trochanter, my experience would lead me to conclude that the explanation which he gives of their presence is false, and that instead they have been developed as the result of excessive strain sustained habitually by the lower portion of the *subscapularis* and by the *pectus* muscles respectively, bone extending along the tendinous attachments of these muscles, and in the direction in which traction is habitually exerted. I have never yet examined throughout the body which presented these or similar prominences in the attachments of muscles and ligaments without being able to satisfy myself completely that they are dependent for their presence upon the habitual transmission of excessive strain through these structures."

¹ Published in the *British Medical Journal*, December 1, 1888.

² *The American Naturalist*, July 1887.

I must remark here that it is surely through an oversight that Mr Lane attributes to the psoas any influence on the third trochanter. When he wrote these lines, either he had the small trochanter in his mind, or he inadvertently put "psoas" for "gluteus maximus." Great credit is due to Mr Lane for his ingenious and thorough examinations of the bodies of those who had long devoted themselves to labours involving certain more or less regular movements. No one doubted that occupation can and does modify the skeleton; but precise studies in this field are of great value. I believe, however, that Mr Lane very much over-estimates the influence of strain on the shape of the bones.

There is one passage in his paper with which I entirely concur:—

"In discussing the variations presented by the skeleton, we are but too ready to shelve their causation if it is not at once obvious, and to fancy that we are explaining the mode of their production satisfactorily by asserting that they are retrocessions to lower types, examples of deficient or abnormal development, or the product of some disease."

This is true, and well said. I have often wondered how the presence of certain structures in animals, sometimes highly specialised ones, outside of any conceivable line of human descent, could *explain* their occasional appearance in Man. None the less they do appear, and, according to Mr Lane's theory, it seems that those of the bones must be accounted for by strictly mechanical causes. His position is essentially that of Dr Julius Wolff,¹ who, writing some twenty years ago on the structure, especially the internal structure, of bone, went so far as to say that from our knowledge of the needs of a bone we can predict its internal structure, and also the converse; further, that a bone is made on the only possible plan. Believing that these views are not in accord with facts, I shall endeavour to show that the third trochanter of the femur and the process for the teres on the scapula cannot, in many cases at least, be accounted for by a mechanical explanation, and further, that it can hardly be doubted that useless and rudimentary structures occur in bones. I must, however, admit that my statement was

¹ *Virchow's Archiv*, Band I, 1870.

too sweeping, and that certain forms of these processes very probably depend upon strain. I lay much more weight on the third trochanter than on the process for the *teres major*. The former is only occasionally found, while the latter is almost always present, though it may be very small. Moreover, I have been able to examine many more thigh bones than shoulder-blades, owing to the fragility of the latter.

A part of the *gluteus maximus* is inserted into the so-called gluteal ridge. The upper part of this is sometimes exaggerated into an elongated roughened crest or protuberance. I hesitate to call this a third trochanter, reserving that name for a smooth, round, or elongated knob, occasionally found in this place or close to it, and which, as I believe Waldeyer and others have remarked, seems to occur with relative frequency on delicate bones. This process, however, is not always smooth, for it may present an acquired roughness which obscures its true significance. Instead of any prominence we may find a long depression, the *fossa hypotrochanterica*, first described by Dr E. Houzé, and more than one of these structures may exist at once.

It is clearly impossible to prove, in the case of any third trochanter occurring in the adult, that there may not have been an excessive strain on the *gluteus maximus*, according to the theory I am disputing; but such a strain must have been due to some particular occupation, and if therefore it can be shown that this process, or even great differences in the degree of roughness, occur frequently in both sexes in prehistoric, in savage, and in but slightly civilised races, in which presumably all lived pretty much the same life, and especially if it occurs in very young persons, not old enough to have been subjected to long-continued strain, the theory becomes so highly improbable as to be untenable.

The first evidence I have to present is from Houzé's monograph *Le Troisième Trochanter*.¹ After recording many observations in comparative anatomy, the author considers ancient human bones, and gives particular attention to the hypotrochanteric fossa. He found this in every Belgian femur of the Reindeer period, and in 60 per cent. of the French ones. He

¹ Bruxelles, 1883.

found the third trochanter in 13 per cent. of these bones. In the Polished Stone Age he found the third trochanter in 38 per cent., the fossa in 20 per cent., and both in 20 per cent. Von Török¹ contributed a very valuable paper to this discussion, but, as his observations were on modern and more or less civilised races, I refer to one point only, namely, that the fossa hypotrochanteric is by no means very rare in modern bones.

Passing to my own observations, I must explain that, except in one or two cases, I have paid no attention to the fossa, and have noted only the different prominences. I have found it impossible to tabulate them to my own satisfaction. Transitional forms are so frequent that it is often very hard to decide to which class a given bone belongs. For this reason I give no percentages of the frequency of the occurrence of the third trochanter. My examinations were made at the Army Medical Museum and the National Museum at Washington, at the Peabody Museum of American Archæology of Harvard College, and at the Hunterian Museum. Of thirteen palæolithic thigh bones from Jefferson College, Tennessee, at the National Museum, three have a small but distinct true third trochanter. Another bone which was injured seems to have a very small one. One or two have a prominence in the gluteal roughness; the rest have none. By the kindness of Professor Putnam I was able to examine many bones of the Mound Builders at the Peabody Museum. Of seventy-four bones from the Kentucky mounds, forty-two have no third trochanter, six have an undoubted one, and twenty-six have a rough prominence, the significance of which is doubtful in many cases. It is to be noted that many of the forty-two without any prominence are large and strong bones. The skeletons from the Tennessee stone graves have, for the most part, been kept distinct. Disregarding several bones, of which the mates were either wanting or injured, I have examined both thigh bones of seventy-four skeletons, with the following result:²—

¹ *Anatomischer Anzeiger*, 1 Jahrg. No. 7, 1886.

² It is proper to remark that these form but a small part of the skeletons of this collection, but at this point I was obliged to interrupt my researches, and it now seems to me that these are enough for the present purpose.

A true third trochanter on both sides (one skeleton doubtful),	1
A true third trochanter on one side only,	2
A rough ridge extending into a probable third trochanter on both sides,	16
On one side only,	2
No true third trochanter on either side,	44
Of this last group thirteen had a considerable rough ridge or surface.	
No true third trochanter on one side—the other doubtful,	2
Total,	74

One of the skeletons, presenting on both sides a rough ridge leading into a probable third trochanter, is that of a child of about ten years; and another, of a person of about eighteen, has a true third trochanter on one side only. I found at the Army Medical Museum twelve skeletons of Sioux Indians, a tribe that has remained savage till within a very few years—

A true third trochanter on both sides,	6
A true third trochanter on one side,	1
A true third trochanter on neither side,	4
A rough ridge of doubtful nature,	1
Total,	12

One of the skeletons, having an excellent specimen of a third trochanter on both sides, was from a girl of about thirteen. It illustrates the fact, already mentioned by v. Török, that this occasional trochanter has no epiphysis of its own. Of three Cheyenne Indians, one has a small knob—a true third trochanter on both sides—the other two a rough prominence. Of three Pueblos one has a strong third trochanter, a distinct knob, on the left, somewhat complicated with roughness on the right. The two others have none. Single skeletons from several other tribes differ considerably, but do not require description. I recently had the privilege of examining the skeletons at the Hunterian Museum. Five Australians show much variation. Of the three females, one has a deep depression for the gluteus maximus, another a small third trochanter on one side, and the third a slight roughness. Of the two males the larger one has a roughened third trochanter. A male West African negro has

a rough ridge, and the female none. On the other hand, two Esquimos have fair third trochanters, three Tasmanians have none, and two Boschiman skeletons are in this respect much alike. I examined the skeletons of six Lapps and Finns at the Washington Army Medical Museum. The Lapp, a female, has a well-marked knob on the right; the left bone is injured. A male Finn, from a grave about 130 years old, with large and strong bones, has no third trochanter. The other four Lapp skeletons were taken from tombs from two to three hundred years old. One, probably female, has a moderately developed trochanter on both sides; another, probably male, a very poor one; a third, probably male, a very large rough prominence; and the last, probably female, has none. Two skeletons of ancient Lapps at the Hunterian Museum show, the male a roughish line, and the female a moderate rough prominence on one side.

These observations show that in wild and in but slightly civilised races there are great discrepancies between different individuals. Among the most important facts are the occurrence of a probable third trochanter in a Mound Builder child of about ten, and especially that of a true one in a Sioux girl of about thirteen. It seems that to attribute this process in all cases to muscular strain, which would involve either some particular long-continued and monotonous occupation, or at least some peculiar method of progression in the case of some of both sexes to which the others were not subjected, is to place theory above evidence or probability.

The process at the origin of the *teres major* from the scapula varies greatly in shape and size, and though when large it is sometimes only an enlarged muscular attachment, in other cases, especially when it is a smooth delicate process on a small scapula, with a tendency to curve towards the ventral surface, I believe its significance is analogous to that of the third trochanter—that it represents a peculiarity found in some animals. Moreover, the size of this process does not always correspond with that of the surface for the origin of the *teres major* on the dorsum of the scapula. Sometimes this space is larger when the process is very small than when it is well developed. I am inclined, however, to differ again from Mr Lane, in holding that in those cases in which the process is probably due to strain the *teres*

major, rather than the lower part of the subscapularis, is the acting agent, for the reason that the teres arises not only from the dorsal surface of the process and from its edge, but sometimes also from a small part of its ventral aspect, so that the border of the process runs into the substance of the muscle.

The usual shape of the Sioux scapula, as deduced from fourteen skeletons, is that of rather a long bone, with the upper border slanting rapidly downward and forward from the superior angle, and with a well-developed process for the teres major. But even in this small series marked variations are not wanting. One skeleton has a small and rounded scapula, in two the upper border runs transversely or nearly so, and the process for the teres varies greatly. It is fairly developed in the girl of thirteen, and small in some powerful skeletons, though in most of the strong ones it is well marked. The scapulæ of three male Cheyennes are very different. This process is large in two and small in one. The shoulder-blades of four Pueblo Indians differ in many respects, including this process. In two female Australian skeletons it is small, but of good size in the third, as it is also in the smaller male, while it is almost wanting in the larger one. All this is in confirmation of what Sir William Turner has already shown,¹ that in savage tribes the shape of the scapula varies greatly, and, for the reasons already given, I hold that it refutes the general applicability of the strain theory.

Another occasional process which it would be very hard to account for by that theory is the supra-condyloid. To the best of my remembrance I have seen it most frequently in rather delicate bones. Comparative anatomy gives no satisfactory explanation of its presence in some animals and its absence in others. Of course, if the strain theory, or any purely mechanical explanation, is true for man it must be true for animals also; and it must explain the presence of such processes as those in question, and it would support Wolff's view of the strict correspondence between a bone's structure and its needs. I attempted three years ago, in a paper on the "Significance of Bone Structure,"² to show that this was not true. "It is hard to believe that the needs for support and motion should be so much alike in the

¹ Report on Human Skeletons in "Challenger" Reports, part xlvii., 1886.

² *Memoirs of the Boston Society of Natural History*, vol. iv., 1886.

Horse and Rhinoceros and so different from those of the Even-toed Ungulata, that the former should require a third trochanter and that the latter should not." Since I wrote these lines I see that Houzé claims to have found a rudimentary third trochanter in some Artiodactyla; but since it is merely a rudiment, the difficulty remains, or is even increased, for it is but an additional instance of a probably functionless structure. A good example of a useless structure is the system of lines on the lower end of the human femur, formerly thought to be caused by the pressure of the semilunar cartilages, but shown by the late Professor Heiberg to be representatives of the more marked separations of the patellar and condyloid surfaces in many animals.

If any one will deny that occasionally occurring structures may be rudimentary and useless, he is bound to show either what purpose they serve or by what mechanism they are produced, and to explain away the remarkable fact of their appearing in places corresponding to those which they normally occupy in certain animals. It is very true that to state this analogy is not to explain the occurrence of these structures, and that in some cases at least an appeal to heredity is absurd; nevertheless, the homology is a fact which we are forced to recognise, even if we cannot fully explain it.

**SOME VASCULAR ANOMALIES OBSERVED DURING
THE SESSION 1888-89. By FRANCIS J. SHEPHERD,
M.D., Professor of Anatomy in McGill University,
Montreal.**

THE following anomalies, which are of some rarity, I have thought of sufficient interest to be placed on record:—

I. Right Subclavian Artery arising from the Descending Aortic Arch—Right Vertebral Artery given off from the Common Carotid—Right Pulmonary Vein emptying into the Vena Azygos Major—Absence of the Levator Ani Muscle.

The subject in which these anomalies occurred died of phthisis in the General Hospital, aged 30. She never had any difficulty in swallowing, nor was she left-handed. There was well-marked rickety deformity of the bony thorax and other parts of the skeleton.

The right subclavian artery arose from the posterior part of the aortic arch, opposite the 3rd dorsal vertebra, passed obliquely upwards over the dorsal vertebræ to the root of the neck on the right side. In its course it went behind the trachea and œsophagus. There was, of course, no innominate artery, the right common carotid arising directly from the transverse arch. The right vertebral arose from the right common carotid at the point where the subclavian is usually given off from the innominate; it passed up the neck to enter the transverse process of the 4th cervical vertebra. The left vertebral arose from the transverse arch between the left common carotid and left subclavian, and entered the transverse process of the 3rd cervical vertebra. The right inferior laryngeal nerve turned around the right vertebral artery instead of the subclavian. The right sympathetic was divided into two cords, which embraced the abnormal subclavian; the superficial cord hooked round the lower part of the artery to join its fellow. This was mistaken at first by the student dissecting the part for the recurrent laryngeal nerve.

The explanation of this anomaly is well recognised, and has been described by Rathke, Wood, Turner, and others. It is an example of persistence of the right aortic root. The fourth arch, from which the subclavian of the right side is usually derived, having atrophied and partially disappeared—that is, the portion external to the origin of the vertebral. The vertebral, then, would represent the shortened fourth arch, and the part of the carotid, as far as the vertebral, the innominate. This

would explain why the right inferior laryngeal nerve recurved around the vertebral artery instead of the subclavian.

In the same subject, on the right side, there was but one *pulmonary vein*. This was of large size, and, in place of emptying into the left auricle, it joined the vena azygos major just before it arched over the root of the right lung. The combined veins emptied into the superior cava. Unfortunately, I only saw this specimen when the heart was in a mutilated condition, and hence could not satisfactorily examine that organ. A part of the blood going to the right lung would have a very small circuit, viz., from the superior cava to right auricle, thence into the right ventricle through the pulmonary artery to the lungs, then back again to the superior cava by the right pulmonary vein, and so on. Thus aerated blood would be continually passing into the venous circulation.

In the same subject the kidneys were supplied by several arteries. The obturator arteries were given off from the epigastrics, and, on the right side, the lingual and facial arose by a single trunk, while on the left side the lingual and superior thyroid arose together. The teeth were very irregular and badly formed, and the superior maxillæ proper distinctly overlapped the inter-maxillary bones.

I might add that in this remarkable subject no trace could be found of the levator ani muscle; its place was taken by pelvic fascia.

II. Absence of the Right Inferior Thyroid Artery, its place being taken by a large branch from the Innominate—Origin of Left Inferior Thyroid from the Left Common Carotid.

This arrangement of the thyroid arteries in the same subject is so rare that, as far as I am aware, no similar case has ever been reported. Two branches only were given off from the transverse arch of the aorta, the innominate and left subclavian. The left carotid was a branch of the innominate. Near the bifurcation of the innominate a large branch was given off, which crossed the trachea and coursed up its left border to supply the lower part of the left lobe of the thyroid gland. As it crossed the trachea it gave off a small branch which ascended the trachea to the gland. This abnormal artery would have been much in the way in performing the operation of tracheotomy.

The right inferior thyroid was a branch of the common carotid three quarters of an inch from its origin; it was of large size, and passed directly up to the right lobe of the thyroid gland. There was no thyroid artery given off from either subclavian artery; the other branches of the axis were given off separately. All four thyroid arteries were of large size.

The absence of the left thyroid may be explained by the fact that the anastomotic branches between the middle thyroid and the left inferior thyroid enlarged abnormally, and in consequence there was a diminution and afterwards a disappearance of the normal inferior thyroid.

In the same subject, from the first part of the right subclavian artery, a large branchial artery was given off, which passed down behind the aortic arch to reach the bifurcation of the trachea. I have several times seen this artery; on one occasion it reached the descending aorta with which it communicated, and I looked upon it as a persistence of the right aortic root.

III. *Double Inferior Cava.*

In this case the external and internal iliac veins of each side united to form a common iliac vein. The left vein passed up on the left side of the aorta and joined the left renal vein, the right iliac vein took the usual position of the inferior cava. These cases are not very uncommon, and I have seen quite a number of examples of this anomaly. Frequently there is a large transverse branch between the two iliacs. These cases of double inferior cava are examples of the persistence of the lower part of the cardinal veins.

IV. *Misplaced Left Kidney with Abnormal Blood Supply.*

In this case the misplaced kidney was situated between the two common iliac arteries. The hilus was placed anteriorly in the centre of the kidney, which was small and of an irregular discoid shape. It received its blood supply from a large artery which came off from the aorta at its bifurcation. The left renal vein emptied into the left common iliac and received the left spermatic. The left supra-renal capsule retained its normal position, and was of large size; it received its blood supply from the left spermatic artery. A similar case was reported in the January (1889) number of this *Journal* by Dr R. B. Mahon.

V. *Multiple Renal Arteries and Veins.*

In this subject both kidneys were placed at a lower level than normal, and reached to the intervertebral substance between the 4th and 5th lumbar vertebrae. The hilus of each kidney was situated in front. The right kidney had three veins going from the hilus to join the vena cava. The left renal vein was of large size and divided into two branches, one of which passed beneath the aorta. A vein of some size united it to the left common iliac¹ vein, whilst another still larger passed for the branch which went over the aorta to the splenic vein. Each kidney, in addition to its normal artery entering the hilus from the aorta, received a branch at its extreme lower end from the common iliac artery of that side.

NOTE.—All the anomalies above described are in the Anatomical Museum of McGill University.

¹ This was probably the remains of the lower part of the left cardinal vein.

THE FLEXORS OF THE DIGITS OF THE HAND.

I. THE MUSCULAR MASSES IN THE FORE-ARM. By BERTRAM C. A. WINDLE, M.A., M.D. *Dubl., Professor of Anatomy in the Queen's College, Birmingham.*

(Read before the Biological Section of British Association, Sept. 1889.)

IN the following paper I intend treating of the arrangement of the muscular bellies of the muscles known in human anatomy as flexor sublimis and profundus digitorum and flexor longus pollicis, reserving for another communication the arrangement and connection of the tendons of the same in the hand, together with their relation to the flexor brevis digitorum, or any of its parts when present. Having first enumerated and sketched the chief characters of the factors which I believe to be constituent of the flexor mass, I shall describe the conditions met with in the chief Mammalian groups, and add a tabulated list of the muscles in fifty-six animals. These last, with two exceptions, duly noted, are from my own dissections.

I must not omit to express my sincere thanks to my friend Mr F. E. Beddard, for the kindness which he has shown me in supplying me with specimens for this and other investigations.

I. *Factors of the Flexor Digitorum Mass.*

Professor Humphry¹ has pointed out that the flexor mass may be looked upon as consisting of three layers—(1) a palmaris longus stratum passing in the hand to the palmar fascia and sheaths of the tendons; (2) a sublimis stratum passing to the second row of phalanges; and (3) a profundus stratum, the most constant of all passing to the terminal phalanges. It is with the second and third of the set, and with their connections with one another, that I am here concerned. The first of these is simple, and contains only one factor; the second is much more complex, and may consist of as many as five portions. Each of these must now be briefly described.

¹ *Jour. Anat. and Phys.*, vol. ii.

Flexor Sublimis is primarily condylar in its origin, but as far as this is concerned depends upon the amount of development of the profundus. Thus when the latter is large in size the sublimis sinks into the position of being a mere fleshy tongue or offshoot from its deeper congener. Such is the case in many of the Carnivora and in some of the Marsupialia. Profundus being somewhat less extensively developed, yet its condylar portions both present and of considerable size, then the still comparatively small sublimis appears to lie in a hollow in the centre of the mass of the deep flexor. When, finally, the sublimis is proportionally more developed than profundus, it encroaches upon the domain of the latter, and may take part of its origin from the bones of the fore-arm.

Flexor Profundus (with which is included *Flexor Longus Pollicis*).—This may consist of five factors, three of which are condylar, two belonging to the bones of the fore-arm solely.

1 and 2.—These two portions come from the internal condyle, one on each side of perforatus. I have applied to them in this paper the terms condylo-radialis and condylo-ulnaris, the latter half of the word in each case signifying the portion of the deeper part into which each enters.

1. *Condylo-Radialis* is the more constant of the two; it arises from the internal condyle to the outer side of sublimis, and passes into the radial side of the common tendon formed by the various constituents of the profundus mass at or near the wrist. It may have a common origin with sublimis in cases where condylo-ulnaris is absent, or all three muscles may arise by a common head.

2. *Condylo-ulnaris* arises from the internal condyle to the inner side of, and generally in common with, sublimis. Its fibres frequently obtain a portion of their origin from the olecranon process of the ulna, or may come entirely from that portion of bone, in which case they cease to belong, strictly speaking, to the condylar group. It has been already mentioned that sublimis may become so much diminished in size as to exist only as an offshoot from profundus. When this is the case, it is from condylo-ulnaris that it comes. Finally, the tendon by which this muscle terminates passes into the ulnar side of the conjoined tendon at the wrist. It should here be mentioned

that condylo-radialis and ulnaris may form a single mass and end in a single flat tendon, passing into the whole breadth of the deeper tendon.

3. *Centralis*.—This, which is also a condylar portion, is a curious muscle, with exceedingly definite connections. It arises under all the other condylar parts from the very edge of the articular cartilage, where the capsule is connected with the bone. It is almost always a slender and perfectly independent muscle, ending in a small tendon often of considerable length, which passes into the deep tendon at its centre. This tendon lies between those of condylo-radialis and ulnaris, when the latter are small, but behind, and still central, when they are large. Although quite distinct, this muscle is nevertheless so closely applied to the under surface of the more superficial condylar portions, and is often so small, that it may escape notice very easily.

4 and 5.—*Radialis and Ulnaris Proprius*.—These portions correspond tolerably closely to the flexor pollicis longus and flexor profundus digitorum in Man. They may be quite separate down to the wrist, or united in their entire extent, covering the interosseous membrane. They may cover all or nearly all of the anterior surfaces of the bones, or may arise only from their upper parts. When separate ulnaris is generally much the larger, a fact correlated in some cases with the absence of condylo-ulnaris as a separate factor. Ulnaris may also consist of two distinct subdivisions, one arising from the olecranon and inner border, the other from the lower end, and these may co-exist with a condylo-ulnaris. Such is the condition, for example, in the Pole-cat and the Otter. Whether separate or combined, radialis and ulnaris form at or near the wrist a broad flat tendon, into which pass the three tendons of the condylar parts, or such of them as may be present.

II. *Flexores Digitorum amongst Lower Animals.*

In this section I shall content myself with briefly describing the arrangement of the flexor muscles in certain groups of animals, relying chiefly on the results of my own dissections, which I have supplemented from various monographs, more detailed information being reserved for the concluding table.

I have not thought it advisable to enter upon the condition of these muscles in Ungulates.

Monotremata.—In *Echidna* there is no separation into parts of the flexor mass, which exists as a single large muscle arising from the lower margin of the internal condyle, and from almost all the ulna from the olecranon downwards. This description tallies with that given by Mivart,¹ who supposes that the portion coming from the internal condyle represents sublimis. From what has been said in Section I., however, it will be seen that it may also include part of profundus. It is, in fact, an example of a simple unsegmented flexor muscle. The condition in *Ornithorhynchus* described by Meckel² is similar to that in *Echidna*.

Marsupialia.—The various factors appear to be fairly independent throughout this group, as will be seen from the table. Sublimis is generally rather small. Thus in *Phalangista vulpina* and *Didelphys virginiana* it is reduced to the condition of an offshoot from condylo-ulnaris. The same condition exists in the Koala (*Macalister*³) and in *Chironectes variegatus* (Sidebotham⁴). It appears to be still more reduced in *Thylacinus*, where Cunningham⁵ says that "the four minute tendons of sublimis have no fleshy bellies, but arise directly from the superficial surface of the rope-like tendon of the profundus."

The same observer remarks that "the nerve supply of the great flexor muscle shows how thoroughly the fibres of the flexor sublimis and the flexor profundus are commingled. Both the ulnar and the median nerves send fibres to the condylar and ulnar portions of the muscle, whereas the radial portion derives its nerve filaments from the median alone."

Edentata.—*Dasypus sexcinctus* possesses a superficial portion passing to the palmar fascia and cartilage; this appears to be a palmaris longus, and, if so, there is no sublimis in the arm. Galton⁶ has, however, described one in this animal. The two condylar portions are closely united, but show a trace of separation in the presence of a longitudinal tendinous intersection.

¹ *Trans. Linn. Soc.*, vol. xxv.

² *Anat. Comp.*, French Trans., vol. vi. p. 333.

³ *Ann. and Mag. of Nat. Hist.*, 1872.

⁴ *Proc. Zool. Soc.*, 1885.

⁵ *Challenger Reports*, pt. xvi. p. 16.

⁶ *Trans. Linn. Soc.*, vol. xxvi.

A few deeper fibres may represent a centralis, which is, however, by no means so distinct as that muscle usually is. According to Macalister¹ there is no sublimis in *Myrmecophaga* or *Manis*; it is quite distinct in *Cyclothurus* and *Pholidotus*, small in *Chlamydophorus*,² and inseparable from palmaris longus in *Bradypus*. *Myrmecophaga* has, according to the same observer, five heads for profundus, viz., (1) tendinous from the inner head of the triceps, (2) from upper two-thirds of the radius, (3) from olecranon, (4) from shaft of ulna, (5) from inner condyle. In *Orycteropus* Humphry³ states that sublimis lies in a channel formed by profundus.

Sirenia.—In *Manatus*, according to Murie,⁴ the flexor forms a complex mass, arising from the internal condyle and from the whole length of the inner aspect of the shaft of the ulna.

Proboscidea.—Miall and Greenwood⁵ describe the flexor communis in *Elephas* as arising by a common tendon with palmaris longus and flexor carpi ulnaris. Another muscular belly arises, deeper than this, from the internal condyle, and passes into the radial side of the first on its deep surface. A third arises from the ulnar, beneath the ulnar origin.

Rodentia.—Sublimis is, in this order, nearly always a somewhat deeply-placed muscle, a fact due to the great size of palmaris longus and flexor carpi ulnaris, which overlap it at its origin and for a certain distance down the fore-arm. Condyloulnaris is very commonly absent. I only found it in *Dasyprocta*, and there combined with condylo-radialis to form a single broad flat tendon, and in *Hydrochoerus*. Centralis is usually present, though I did not notice it in *Erethizon* or *Hydromys*; in *Cynomys ludovicianus* it arises in common with sublimis, which is an unusual arrangement. It may be finally noted that radialis and ulnaris not unfrequently arise only from the upper portions of their bones.

Insectivora.—In *Talpa* the flexor mass forms one single unsegmented muscle, from which comes a strong tendon. In

¹ *Trans. Roy. Irish Acad.*, vol. xxv. p. 49.

² *Ibid.*, p. 219.

³ *Jour. Anat. and Phys.*, vol. ii.

⁴ *Trans. Zool. Soc.*, vol. viii.

⁵ *Jour. Anat. and Phys.*, vol. xii.

Erinaceus, on the contrary, all the factors are present, ulnaris and radialis proprius coming only from the upper portions of their bones.

Pinnipedia.—In *Phoca* (Humphry¹) *sublimis* is a thin delicate muscle, arising from a fascia on the surface of profundus, which latter arises from the internal condyle and from both bones of the fore-arm. In *Otaria jubata* (Murie²) *sublimis* has two heads of origin—(1) condylar and ulnar, (2) ulnar, from the inner surface of the olecranon to the centre of the bone. Profundus arises from the radius and ulna. He remarks, however, that “there is more or less union by fascial expansion of *sublimis* and profundus and intimate muscular and partly tendinous conjunction of the latter with flexor longus pollicis, which produces a certain simultaneous movement of the whole palmar surface of the manus when the muscular bellies are contracted.” *Trichechus rosmarus* (Murie³) possesses what may either represent the flexor *sublimis digitorum*, or, combined with it, the flexor profundus digitorum. It is a double-bellied muscle, one half, as in *Otaria*, arising from the internal condyle and capsular ligament, and the other from the outer side of the ulna below the olecranon, and these two elongated fleshy bellies run separately to the wrist-joint, each being tendinous, however, one inch above that;” with these is a radial flexor longus pollicis.

Carnivora.—Throughout this order *sublimis* seems to be reduced to a minimum, as it nearly always exists as a mere offshoot from condylo-ulnaris near the lower end of the fore-arm. Condylo-radialis was present in all the specimens which I examined, and condylo-ulnaris in all but *Ursus americanus*, in which I could find no trace of it. The two may be combined into a single belly with a single flat tendon, as in *Meles*, or as a kind of intermediate stage between this condition and that of complete separation, the single belly may divide into two short tendons just before they pass into the deeper portion, as is the case in *Viverricula* and *Galictis*. Centralis is generally present, as it is in *Canis*, though Krause⁴ does not mention its presence.

¹ *Jour. Anat. and Phys.* vol. ii.

² *Trans. Zool. Soc.*, vol. viii.

³ *Ibid.*, vol. vii.

⁴ *Anat. des Kaninchens.*

Ulnaris may consist of two distinct portions, as has already been mentioned.

Cheiroptera.—In *Pteropus medius* there is a central condylar portion, which may be a sublimis, as Humphry¹ believed, on each side of which is a slip going down to radialis and ulnaris respectively. Macalister² considers the first portion to be a palmaris longus, because it runs over the main part of the annular ligament, has metacarpal insertions, and gives a polliceal slip, and this view appears to me to be probably correct. The last named writer states that the flexor communis has condylar, radial, and ulnar origins in *Pteropus edwardsii*, *Vampyrops*, *Cephalotes*, *Cynonycteris amplexicaudatus*, and *Artibeus jamaicensis*.

Prosimiae.—In *Nycticebus sublimis* and condylo-radialis come off together. There is no condylo-ulnaris nor centralis. In Mivart and Murie's³ monograph on this order, sublimis is described in *Lemur catta* as small, originating from the internal condyle and sending down a slip to the radial portion of the deeper part. This slip is my condylo-radialis. The same condition exists in *L. varius* and *Galago crassicaudatus*. "In specimens of *G. allenii*" they state:—"We observed that the tendon united with the profundus, when pursued up the arm, was that which formed the superficial slip." Profundus has condylar, radial, and ulnar portions, with what appears to be a centralis in *Galago crassicaudatus* and *G. allenii*. Tarsus, according to Burmeister, seems to possess (1) condylo-radialis, (2) radialis proprius, (3) centralis (?), (4) olecranal, receiving slip from sublimis, and probably representing condylo-ulnaris, (5) ulnaris proprius.

Pitheci.—In this order sublimis is much larger proportionately than in most of the others, and extends in the higher forms its site of origin lower down so as to reach the radius. In all save the higher group there appears to be a condylo-radial slip, but I only found a condylo-ulnar in *Hapale*, and there very small. Centralis I only met with in a *Cebus capucinus*; it was of very small size, and may have been an individual variety.

¹ *Jour. Anat. and Phys.*, vol. iii.

² *Phil. Trans.*, 1872, p. 125.

³ *Trans. Zool. Soc.*, vol. vii.

III. *Flexores Digitorum in Man.*

In *Man* the *sublimis* retains the comparatively large size and extended origin which it possesses in the higher Apes. *Profundus*, and in this term I include the polliceal portion, is somewhat smaller than the average amongst mammals, and only at times retains traces of its condylar heads. Of these, the most common is the slip to the polliceal portion, which may arise either from the internal condyle of the humerus, or, receding still further, from the coronoid process of the ulna. This slip corresponds to the condylo-radial, and it is interesting to observe that, as it is the most frequent in *Man*, so also it is the most constant throughout the *Mammalia*, and persists throughout the greater number of the Apes, where condylo-ulnaris may be said to fail altogether. Condylo-ulnaris is represented by the so-called *accessorius ad flexorem profundum* of Gantzner, which may come from the coronoid process or from the condylar origin of *sublimis*. *Centralis* may also, I believe, be present, as in two instructive cases which I observed in the dissecting-room during the course of the past winter session. In each of these arms there was a slip from the condylar origin of *sublimis* to *flexor longus pollicis*, viz., condylo-radialis. Besides this, there were two slips, coming in the one case with *sublimis* from the internal condyle, and in the other with the same muscle from the internal lateral ligament. These slips passed one into the radial, the other into the ulnar, border of *flexor profundus digitorum*. The latter I regard as condylo-ulnaris, and I think there can be little doubt that the former was the representative of *centralis*. It is very interesting to find all three of the condylar heads of the *profundus* present in two examples.

Before passing away from these muscles, I may here remark that the variations in their size and position throughout the *Mammalia* throw some light upon a question recently debated in connection with the second set of extensors of the hand, Professor Bland Sutton maintaining that these, or rather the missing members of the group, gradually passed downwards in the process of regression, Dr Brooks, on the other hand, considering that they had originally been an *extensor brevis*

digitorum, and gradually travelled upwards. I think the facts point to the conclusion that fore-arm muscles have, in a state of regression, a tendency to travel downwards in all cases. For example, the flexor sublimis in Carnivora and other forms, where diminished in size, passes downwards so as to lose all free connection with its ordinary superior attachments. Moreover, as I shall hope more fully to show hereafter, the proximal portion of the muscle may be lost and the distal persist with a lower attachment. I have pointed out that the steps of this process may be observed in the Ursidæ.¹ Thus "in *Nasua* the perforated tendon comes from sublimis; in *Ursus* it does so also, but gives a slip to pisiform as well. In *Cercoleptes* the proximal portion of the muscle has disappeared, but the distal arising from the pisiform is still perforated. Finally, in *Procyon* it no longer has any perforation, but is only connected with the sheath of the tendon of the deeper muscle."

Again, where profundus loses its predominance in size, probably by the passage along sublimis of muscular fibres which might have passed into the deeper stratum, it recedes, retaining, however, traces of its connection with higher points. If the second set of extensor muscles be, as I suppose it will be allowed they are in Man, in a state of regression, it seems probable that they will follow or are following the same rule and gradually travelling downwards from their original condylar origin to lower parts of the fore-arm. In this connection I may mention that I saw during this summer session, in the dissecting-room, an arm where the extensor indicis had become displaced downwards so as to arise from the lower border of the radius just where the capsular ligament has its attachment.

I reserve any general conclusions as to the cause of the difference in size and number of the flexor muscles for a further communication, in which I hope to deal with the condition of these muscles in their relation to the digits.

¹ *Jour. Anat. and Phys.*, vol. xxiii. p. 85.

IV. *Table of Flexores Digitorum.*

+ = present. - = absent. W = conjoined with.

	SUBLIMIS.	PROFUNDUS.				
		Condyloradialis.	Condyloulnaris.	Centralis.	Radialis.	Ulnaris.
<i>Echidna lawesii</i> , <i>Hypsigrymnus rufescens</i> ,	See p. 75. + Small.	...	...	...	...	...
<i>Phalangista vulpina</i> ,	+ An offshoot from cond.-uln.	+	+	+	+	+ Much larger than rad. +
<i>Dasyurus viverrinus</i> (Macconnick), ¹	+ W. cond.-uln.	+	+	+	+	+
<i>Petrogale penicillata</i> ,	+ Sppl. pt. of cond. rad.	+	-	-	+ Join high only arise from parts of	+ up and from upper bones.
<i>Petrogale xanthopus</i> ,	+ Do. do.	+	-	-	+ Do. do.	+ Do. do.
<i>Didelphys virginiana</i> ,	+ An offshoot from cond.-uln.	+	+	+ Small.	+	+ Large.
<i>Dasyus sexcinctus</i> ,	-†	Closely combined and only to be distinguished by central tendinous intersection.		!	+ Comparatively small.	+ Large.
<i>Lepus cuniculus</i> ,	+ Much covered by pal. long. and flex. carp. uln.	+ Very large.	-	+	+ Rather small.	+
<i>Lepus timidus</i> ,	+	+	-	+	+ Small, with long tendon.	+
<i>Cavia cobaya</i> ,	+	+	-	+	+ Combined.	+
<i>Coelogenys paca</i> ,	+	+ Large.	+ Large.	+	+ Very small.	+
<i>Dasyprocta cristata</i> ,	+ W. cond.-uln.	+ Combined forming single broad tendon.	+ +	-	+ +	+
<i>Hydrochaerus capybara</i> ,	+ W. cond.-uln.	+ Large.	+ +	+	-	+
<i>Sphingurus prehensilis</i> ,	+	+	-	+	+ Combined.	+
<i>Erethizon epixanthus</i> ,	+	+	-	-	+	+

¹ *Jour. Anat. and Phys.*, vol. xxi.

IV. *Table of Flexores Digitorum*—continued.

	SUBLIMIS.	PROFUNDUS.				
		Condyloradialis.	Condyloulnaris.	Centralis.	Radialis.	Ulnaris.
Myopotamus coypus,	+	+	-	+	+	+
Lagostomus trichodactylus,	+	+	-	+	+	+
					Small and nearly symmetrical from upper parts of bones.	
Mus decumanus,	+	+	-	+	+	+
Hydromys chrysogaster,	+	+	-	-	Very small.	+
	W. cond.-rad.				+	+
Cynomys ludovicianus.	+	+	-	+	+	+
	W. centr.			Conn. at origin with perforat.	Chiefly from parts of bones.	
Castor canadensis,	+	+	-	+	+	+
Sciurus vulgaris,	+	+	-	+	+	+
Erinaceus europeus,	+	+	+	+	+	+
	W. cond.-uln.				From upper parts of bones.	
Talpa europæa,	See p.	...	...	...	...	...
Procyon cancrivorus,	+	+	+	+	+	+
	W. cond.-uln.			Represented by tendon from under surface of Pfn.		
Cercoleptes caudivolvans (Beswick-Perrin), ¹	+	+	+	-	+	+
Ursus americanus,	+	+	-	+	+	+
Nasua rufa	+	+	+	+	+	+
	W. cond.-uln.				Combined.	
Meles taxus,	+	+	+	+	+	+
	An offset from cond.-uln.	Combined to form a single flat tendon.				
Mustela putorius,	+	+	+	+	+	+
	Do. do.					Two. 1. Olecrn. and inner border. 2. Lower end.
Lutra vulgaris,	+	+	+	+	+	Two. As above.
	Do. do.					

¹ Proc. Zool. Soc., 1871.

IV. *Table of Flexors Digitorum*—continued.

	SUBLIMIS.	PROFUNDUS.				
		Condyloradialis.	Condyloulnaris.	Centralis.	Radialis.	Ulnaris.
<i>Viverricula malaccensis</i> ,	+ An offset from cond. masa.	+ A combined mass at first, which divides into two	+ tendons.	+	+ Both	+ small.
<i>Genetta tigrina</i> ,	+ W. cond.-uln.	+	+	+	+ Combined.	+
<i>Herpestes griseus</i> ,	+ Offset from cond.-uln.	+	+	+	+	+
<i>Herpestes nepalensis</i> ,	+ W. cond. parts.	+	+	-(?)	+	+
<i>Paradoxurus typus</i> ,	+ W. cond.-uln.	+	+	+	+	+
<i>Cynictis penicillata</i> ,	+ A minute offset.	+	+	+	+ Both	+ small.
<i>Galictis vittata</i> ,	+	+ A combined mass at first, which divides into two	+ tendons.	-	+	+
<i>Ictonyx zorilla</i> ,	+ An offset from cond.-uln.	+	+	+	+ Combined.	+
<i>Canis familiaris</i> ,	+ W. cond.-uln.	+	+	+	+	+
<i>Felis domestica</i> ,	+	+	+	+	+	+
<i>Pteropus medius</i> ,	+(?)	+	+	-	+	+
<i>Nycticebus javanicus</i> ,	+ W. cond.-rad.	+	-	-	+	+
<i>Hapale jacchus</i> ,	+	+ Large.	+ Very small, long tendon.	-	+ Combined.	+
<i>Midas rosalia</i> ,	+ W. cond.-rad.	+	-	-	+ Largely from ulna.	+ Inner border of ulna.
<i>Cebus capucinus</i> ,	+ Do. do.	+	-	+ Very small, with long slender tendon.	+	+
<i>Cynocephalus maimon</i> ,	+ Do. do.	+	-	-	+ Combined.	+

IV. *Table of Flexors Digitorum*—continued.

	SUBLIMIS.	PROFUNDUS.				
		Condyloradialis.	Condyloulnaris.	Centralis.	Radialis.	Ulnaris.
Macacus erythraeus,	+	+	-	-	+ From upper third of	+ bones only.
Macacus cynomolgus,	+	+	-	-	+ Combined.	+ +
Cercopithecus diana,	+	+	-	-	+	+
Cercopithecus callitrichus,	+	+	-	-	+	+
Cercopithecus campbelli,	+	+	-	-	+	+
Cercopithecus lalandii,	+	+	-	-	+	+
Cercopithecus cephus,	+	+	-	-	+	+
Orang utang,	+	-	-	-	+	+
Homo,	Has a radial origin. + Do.	Commonly present as second head of flex. long. pollicis.	Occasionally present.	Rarely present.	Flexor longus pollicis.	Flexor profundus digitorum.

THE GUSTATORY ORGANS OF *BELIDEUS ARIEL*.

By FREDERICK TUCKERMAN, M.D., *Amherst, Massachusetts*. (PLATE V.)

I AM indebted to Professor John M. Tyler, of Amherst College, for kindly placing at my disposal a tongue of this animal.

The organ measures 21 mm. in length, 6 mm. in breadth, and 5 mm. in thickness. Anteriorly, it is free from the frænum linguæ for 9 mm. The upper surface is transversely impressed, corresponding to the roof of the palate, which is traversed by several small elevated ridges slightly curving forwards. Fungiform papillæ are thinly scattered over the dorsum. They are very small, averaging only about 0.20 mm. in height.

At the posterior part of the dorsal surface, directly in the median line of the tongue, and 3.5 mm. from the base, is situated a single circumvallate papilla. About 1 mm. anterior to this papilla, and 2 mm. distant from each other, are two short furrows, running parallel to the long diameter of the tongue. The papilla and furrows thus form a triangle, the apex of which looks towards the epiglottis. The furrows lie somewhat concealed, and are scarcely distinguishable without a lens. At the bottom of each furrow is a ridge, which bears taste-bulbs over nearly its entire surface. Although no search was made for the lateral gustatory organs, there is little doubt of their existence, as they have been found in every marsupial in which the taste-areas have been studied. Poulton¹ mentions finding them in *Phalangista*, though with a less number of furrows, and with a less regular arrangement than in the higher *Mammalia*.

The Circumvallate Papilla.—This papilla measures 0.55 mm. at its widest part, and is 0.54 mm. in height. The upper surface, which overtops the adjacent lingual surface a trifle, is marked by vertical clefts, the spaces between which are filled nearly to a common level by the epithelium. The sides are fairly symmetrical, and at their lower part bend inwards and

¹ *Quart. Jour. Micr. Sci.*, vol. xxiii., 1883, p. 471.

downwards. The trench, which is nowhere very wide, becomes gradually narrower as it curves inwards at the base of the papilla. Serous glands are fairly abundant, and their ducts discharge into the trench at its lower part.

The taste-bulbs of this gustatory area are chiefly confined to the lower half of the lateral wall of the papilla, which they almost completely fill. They are disposed in six to eight tiers. Bulbs are also present in the epithelium lining the bottom of the trench, and isolated ones occur at the upper angle of the outer wall of the latter. The bulbs have more or less of a neck, and bear a resemblance in their general contour to those of the Rabbit and Musk-Rat. They measure 0.044 mm. in length, and are 0.022 mm. in breadth. In transverse sections of a bulb, having a diameter of 0.021 mm., I counted eleven cells grouped about the axis of the bulb, most of which were probably sensory cells.

Nerve-fibres, many of them non-medullated, enter the axis of the papilla, and their branches run to its upper part and sides. Beneath the bulb-bearing region they form a plexus, from which terminal fibrils (many of them having a primitive sheath), run either directly to the bases of the bulbs, or pass between them and enter the epithelium. A great number of very delicate fibrils enter the epithelium, and there form a network. Other intra-epithelial nerve-fibrils appear to end freely, while still others terminate in loops. At the upper part of the papilla were what seemed to be rather large ganglion cells, but owing to certain alterations which their constituent elements had evidently undergone, I was unable to positively identify them as such.

The Gustatory Ridges.—The bulb-bearing ridges of *Belideus ariel* are two in number. Each ridge rises from the bottom of a deep furrow or groove, the crown of the ridge at its highest point being 0.1 mm. below the opening of the latter. Anteriorly, the ridge is not unlike a deeply sunk circumvallate papilla. As it is followed backwards, however, it grows smaller, and becomes more perfectly arched. At the posterior limits of the ridge, the furrow is wholly closed above, thus protecting completely the portion of ridge beneath it (the figs. 2-6 show the general shape of the ridges). Serous glands are scattered

through the membranous stroma underlying the ridge, and their ducts open into the furrow at its base and deeper part.

The taste-bulbs seem to almost fill the epithelium covering the ridge. Some of the largest bulbs are 0.054 mm. long and 0.027 mm. broad, but the average bulb is not more than 0.042 mm. in length and 0.021 mm. in breadth. They appear to be rather loosely constructed, and of a somewhat lower type of terminal sense-organ than the bulbs of the circumvallate papilla. The gustatory pores vary slightly in size and form. They are usually, however, more or less oval, and their diameter is about 0.0033 mm. Many of the bulbs lie partly in the epithelium and partly in the mucosa, but I failed to detect any which were wholly subepithelial in position. This taste-area is abundantly supplied with nerves. Nerve-fibres enter the base of the ridge, and their branches radiate apparently to all parts of it. The distribution and arrangement of the terminal fibrils is similar to that which exist in the circumvallate papilla.

We are indebted to Poulton for first directing the attention of anatomists to the gustatory ridges of Mammalia. This observer found at the posterior part of the dorsal surface of the tongue of *Ornithorhynchus* two pairs of these ridges. The anterior pair lie below the surface in a furrow. The posterior pair are likewise in a furrow, but their crests are on a level with the adjoining lingual surface. The ridges of both areas bear taste-bulbs over the whole of their convexity.¹

There exist in the gustatory ridges of *Belideus ariel* structural characters which are common to both the circumvallate type of taste-area and the bulb-bearing ridges of *Ornithorhynchus*. The ridges of *Belideus* furnish us with an intermediate or transitional stage in the process of development of the former from the latter, the more recent from the more primitive type of taste-area. Consequently, the finding of these ridges supplies an important link in the history of the development of gustatory areas. Now that the two types have been found to occur together, it is not at all improbable, from all indications, that further investigation will reveal the foliate

¹ Poulton's admirable description of the tongue and gustatory organs of *Ornithorhynchus* may be found in the *Quarterly Journal of Microscopical Science*, vol. xxiii., 1883, p. 453.

type, though doubtless in its simplest form, coexisting with them.

The Fungiform Papillæ.—Taste-bulbs were more plentiful on these papillæ than I had expected to find them. Those about the tip are seldom without one or more at their upper part. The bulbs, when single, lie vertically in the long axis of the papilla. When two are present, they are placed obliquely, with apices directed upwards and outwards. The bases of the bulbs in most instances rest in depressions of the mucosa. Some of the bulbs have a well-defined neck, while others are without it. They vary in length from 0.039 mm. to 0.044 mm., and in breadth 0.024 mm. to 0.030 mm.

EXPLANATION OF PLATE V.

Reference Letters.

<i>f</i> , Furrow.	<i>pp</i> , Papillary processes of
<i>gl</i> , Serous gland.	mucous membrane.
<i>gld</i> , Duct of serous gland.	<i>sp</i> , Secondary papillæ.
<i>gr</i> , Gustatory ridge.	<i>t</i> , Trench.
<i>mm</i> , Mucous membrane.	<i>tb</i> , Taste-bulb.
<i>n</i> , Nerve.	

Fig. 1. Vertical section through the circumvallate papilla. $\times 50$.

Fig. 2. Vertical section through the anterior part of the left gustatory or bulb-bearing ridge. This portion of the ridge, although entirely below the surface, is in many respects not unlike the circumvallate papilla of some of the higher mammals. The taste-bulbs are confined to the lateral area. $\times 60$.

Fig. 3. Vertical section through the anterior part of the same ridge. The ridge has lost its apex, and the bulbs are arranged in a continuous belt entirely covering its crest and sides. $\times 60$.

Fig. 4. Vertical section through the middle of the same ridge. The ridge has decreased in size, and the opening of the furrow has become much narrower. $\times 60$.

Fig. 5. Vertical section through the posterior part of the same ridge. The lips of the furrow have coalesced, and the ridge is completely roofed over. $\times 60$.

Fig. 6. Vertical section through the extreme posterior part of the same ridge. The ridge is smaller and more constricted at the base. The bulbs are distributed over the circumference, and are of a more simple type than those at the anterior end of the organ. $\times 60$.

Fig. 7. Vertical section through a fungiform papilla of the tip of the tongue, bearing a single taste-bulb at its upper part. $\times 100$.

Fig. 8. Vertical section through a fungiform papilla from the mid-dorsal surface of the tongue, bearing two taste-bulbs at its upper part. $\times 130$.

CONTRIBUTIONS TO THE COMPARATIVE OSTEOLOGY OF ARCTIC AND SUB-ARCTIC WATER-BIRDS. PART V. By R. W. SHUFELDT, M.D., C.M.Z.S. (PLATES VI, VII, VIII)

(Continued from vol. xxiii. page 558.)

Of the Skeleton in the Puffins (Subfamily Fraterculinæ).

IN our avifauna we recognise four species of Puffins which inhabit the coast-lines and islands of the polar seas of both the North Atlantic and Pacific. These are *Fratercula arctica* (the only species on the Atlantic side), *F. a. glacialis*, *F. corniculata*, and *Lunda cirrhata*.

The study of these odd birds has always had a peculiar fascination for me, and it proved to be a great pleasure when I came to draw the views of their skulls shown in Plate VI. of this Part.

The series of skeletons representing the subfamily, now at my hand for a more complete examination, is exceptionally fine, though of *Fratercula arctica* I have but a skull, hyoid arches, and a few of the leading cervical vertebræ.

No doubt the skeleton of this Puffin is very similar to that of *F. corniculata*, of which there are several skeletons. In the osteology of these curious birds, there is, as we might expect, much that connects them with other representatives of the **ALCIDÆ**.

This part of their structure says as plainly as could be in words, that they are Auks beyond question, and they not only have characters in common with the genus *Simorhynchus*, but many that point to their relationship with the other subfamilies.

To better enable us to compare the characters of the skull in these Puffins, I have, as I have just said, on Plate VI., given the lateral views of the leading types of the genera to be investigated. These will give a clearer idea of the quaint appearing skulls of these grotesque birds than we could gain through any mere verbal description. Aided by the high ramal walls of their mandibles, these skulls are noted for their striking vertical

depth, their lofty and laterally compressed superior mandibles, and their orbits, whose outer boundaries have such a square appearance (compare the latter with *Alca*).

*List of Osteological Material examined of the Subfamily
Fraterculinæ.*

Specimens.	Where Collected.	Collector and Donor.	Catalogue No. of Smithsonian Institution Collection.	Remarks.
<i>Lunda cirrhata.</i>	Farallone Islands.	...	16,971	Skeleton.
" "	" "	" "	16,972	" "
" "	Amchitka Islands, Alaska.	W. H. Dall.	13,656	Skeleton.
" "	" "	W. H. Dall.	13,657	" "
" "	" "	" "	13,665	" "
<i>Fratercula corniculata.</i>	Kyska.	" "	13,655	" "
" "	Adakh.	" "	13,652	" "
" "	" "	" "	13,654	" "
" "	Kyska.	" "	13,652	2 specimens of this number.
" "	Adakh.	" "	13,653	Skeleton.
<i>Fratercula arctica.</i>	" "	" "	16,994	Skull.
<i>Lunda cirrhata</i> , ♀	Altu.	W. H. Dall.	13,660	Sternum.
" "	" "	" "	13,659	" "
" "	Kyska.	" "	13,661	Sternum, &c.
" "	" "	" "	16,995	Dried head.
" "	" "	" "	16,996	" "
" "	" "	" "	16,997	" "
" "	Adakh.	W. H. Dall.	13,658	Skeleton.

Soon after leaving the cranio-facial region, the culmen in the skull of *Fratercula arctica* rises in a mound-like prominence, having its convex summit proper and another convexity just beyond its posterior base. This elevation is considerably higher than the level of the posterior part of the skull. From its summit the culmen falls in a sharp median edge to the mandibular apex, the bone being nearly as thin as a knife blade anterior to and above the narial opening. The edge of the superior mandible is sharp and gently curved downwards; its apex is hooked, the hook being directed downwards and forwards.

These birds are all of the schizorhinal type, and their stout

nasal bones, of uniform width, descend quite abruptly to meet the dentary processes of the premaxillary.

The narial openings, so small and slit-like in the living birds, are here, as may be seen by the figures, very sizable apertures.

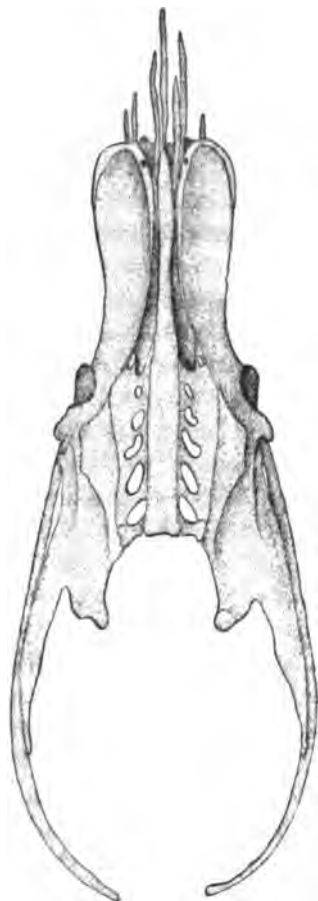


FIG. 1.—Pelvis of *Lunda cirrhata*, seen from above (specimen 13,656, Smithsonian collection); life size.

This aspect of the mandible differs in *F. corniculata* simply in having but the single peak to the mounding culmen, the posterior and lower one not developing.

In *Lunda cirrhata* the culmen in this region is barely elevated at all, and not enough to attract particular attention.

All its anterior half, however, is strongly impressed by the powerful corneous sheath it wears in life. Indeed, fully the anterior half of the osseous narial aperture is obliterated by the backward extending bone which supports this horny covering. The extent to which this is carried varies in different individuals of this genus, but it is always sufficient to create a straight border to the anterior extremity of the narial opening—nearly half in all cases.

Fortunately I find among the skulls of *L. cirrhata* in my hands three or four of an age sufficiently young to show all the sutures among the bones. From these I find that the superior mandible is not nearly so high in the immature specimens; the horny sheath of the beak does not make its impress upon the sides of the osseous one; and that the backward extension of the bone over the nostril to support it increases with advancing age, being very little in extremely young birds.

These differences in the conformation of the superior mandible constitute the main ones for the skull among these Puffins, so that the description which now follows will apply to them all; any minor deviation from the common plan, on the part of any genus, can be briefly alluded to, and separately described.

The *lacrymals* are very small, their contracted summits forming the highest points in the frontal region. They articulate principally with nasals, and only to a limited degree with the frontals. Their descending and spiculaform processes early anchylose with the outer borders of the quadrate, rather ample ethmoidal wings.

The peculiar *turbinated bones* of the rhinal chamber, that spring from the anterior aspects of these latter, have already been sufficiently described above.

Extremely interesting do we find the several articulations of the nasal, maxillary, palatine, and associated bones. The schizorhinalism of the first-mentioned element is beautifully developed in young specimens of *Lunda cirrhata*, though the necessity of its being so is by no means so evident. The nasals make an extensive longitudinal suture in the median line, which is in continuation with the median suture of the nasal processes of the premaxillary.

In very young birds of this genus the superior fork of a nasal is not produced so far as the anterior margin of the nostril, but later the backward growth of bone of the antero-lateral wall of the superior mandible reaches its apex. The maxillary process of a nasal fails in its descent to quite reach the extremity of the dentary process of the premaxillary, the little intervening space being filled in by the maxillary.

This latter bone sends upwards a splint-like process that is closely applied to the inner aspect of the corresponding nasal, nearly as far up as the postero-superior angle of the nasal opening or nostril of the skull. It also sends forwards a broader process, that, assisted by the fellow of the opposite side, forms all there is to the imperfect floor of the rhinal chamber anterior to the maxillo-palatines. This process of a maxillary then tapers off to a point anteriorly, lying on top of, and in close connection with, the corresponding palatine, which is wedged in between it and the dentary process of the premaxillary, the palatine being carried to a point opposite the anterior margin of the nostril of the skull, where it ends, the maxillary not extending quite so far.

The posterior process of a maxillary is long and slender, and conforms to the quadrato-jugal bar. Internally, it develops a large maxillo-palatine, which will be described further on.

An ethmoidal wing does not reach by its superior border the roof of the skull above, while its inferior border is straight, to be produced on the side of the mesethmoid as a thickened brace as far as the rostrum.

The integrity of the inter-orbital septum and the anterior wall of the brain-case varies in these birds. As a rule, however, in very old birds, there is a large vacuity in its centre; another occurs along the track of the olfactory, while possibly the foramen opticum may be found entire, although in the series before us it is only completely formed so in the specimen of *F. arctica*, in which bird also the anterior wall of the brain-case is more complete.

The skulls in Plate VI. of this part, and figs. 7, 13, and 17 of Plate VII., all show very well the peculiar post-frontal wings on the lateral aspect in this Puffin. When describing some of the Guillemots, I showed how these were eventually brought about

by the absorption of certain portions of the margin of the orbit, and the floor of the supraorbital glandular depressions. It will now be interesting to note from the immature skull the bones that go to and from this post-frontal wing. In this we may be assisted by such a form as *Centrocerus urophasianus*, where there are two prominent processes found upon the lateral aspect

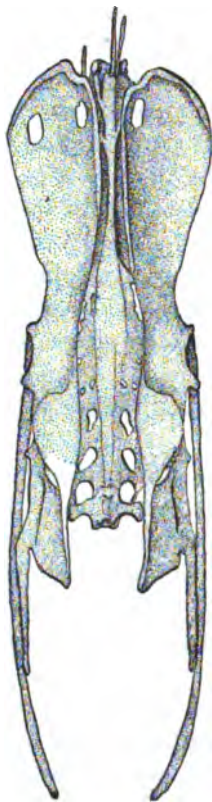


FIG. 2.—Pelvis of Brünnich's Guillemot, seen from above. (Specimen 16783, Smithsonian Collection); life size.

of the skull above the quadrate: these are—the sphenotic or post-frontal, developed on the part of the alisphenoid, and the squamosal developed by the squamosal. These unite at their distal apices in the adult fowl to bridge over the temporal fossa.

I find this post-frontal wing in the young of *Lunda cirrhata*

developed entirely by the squamosal, as the squamosal process proper is, while the alisphenoid and the frontal simply abut against its antero-inferior base or margin.

The alisphenoid, however, in this young Puffin is not altogether without a sphenotic process, for the very abutment we speak of here too projects to some extent outwards and slightly downwards, and no doubt forms the lower tip of the particular wing in question, and thus fulfils, at its lower extremity at least, the same conditions we find to exist in the Sage Cock.

Puffins have the crotaphyte fossæ confined to the lateral aspects of the skull, and divided from the hinder end of the supra-orbital glandular depression on either side by a narrow isthmus of bone, which latter is continued up on each post-frontal wing.

Upon the posterior aspect, the occipital area is defined by a fairly-developed and raised line. It forms the posterior margins of the auricular wings, and passes over the top of the supra-occipital prominence, in which latter locality it is not so strongly marked. This last-mentioned elevation is fully as large as we found it in the Razor-bill and Murres. It may or may not have the large elliptical supra-occipital foramen on either side of it. Specimens in the series at my hand show these in all stages of development, from its complete absence, as in the side view figure of *F. arctica* (Plate VI.), to its condition as seen in fig. 7 (Plate VII.), where also a small median and perfectly circular foramen occurs likewise above the latter.

A superior view of one of these skulls shows the thin, knife-like edge of the anterior half of the column, the broad convex area behind it (most so in *L. cirrhata*), where in all the species the premaxillary ends are more or less distinctly marked. We also are to note the supra-orbital glandular depressions here, as in most Auks, occupying the entire narrow fronto-interorbital space, being divided by a sharp median line, after which they curve about posteriorly to bound the orbital margins behind, to be separated from the crotaphyte fossæ, as already described.

These details are all well shown in fig. 13 of Plate VII. for *Fratercula arctica*.

Upon an under view of the skull we observe that the bounding edges of the bill are cultrate, and much raised above

any of the parts about them. The anterior half is longitudinally scooped out all the way to the apex; behind this we fall into the internarial space. In *L. cirrhata* we have seen that this has lateral walls in front, which are developed as described above.

The body of the ethmoid shows the transverse division beneath the line of the cranio-facial hinge. Its anterior triangular piece sometimes comes free in ordinary maceration of the skeleton of one of these Puffins.

The vomer agrees in all respects with *Alca* and *Uria*. Maxillo-palatines are splendidly developed, being large sub-circular discs, not spongy (except in the young), convex towards the vomer, which they hide in lateral view, and concave outwards, the way they almost directly face. They make attachments to the usual bones, but in *L. cirrhata* they are so lofty and large that special bony braces are developed to support them. These spring from the maxillary near the foot of the nasal on the inner side, and are thrown up against the convex surface, inwards and backwards, to ankylose at points near the margin. These braces are usually two in number to each maxillo-palatine, and are found in the young birds. *Fratercula* seems to be without them in all the skulls I have examined, and I am of the opinion they do not occur in that genus, as the bones are not quite as lofty, and hence do not need them.

Each maxillo-palatine has a little spine upon its anterior edge, which may be seen beyond the nasal upon lateral view, as shown in the skulls in Plate VI.

The *palatines* (Plate VII fig. 17) are arranged as we find them among the Auks generally. They make the same character of articulation exactly with the rostrum, the pterygoids, and the vomer. They are, however, more curved downwards than is the rule with the others, and thus show distinct inner and outer carinations. Their postero-external angles are invariably nicely and evenly rounded off.

The pterygoids are nearly straight and slender; their anterior heads meet and grasp the rostrum as well as the heads of the palatines.

Sometimes the faintest possible sign of rudimentary basi-ptyergoid processes are seen, in the form of minute prickles at the usual sites.

My search for an *os uncinatum* among the skulls of these Puffins has been unsuccessful, but future observers may be more fortunate. The quadrate agrees with that bone as found in the other Auks.

The postero-external angles of the basi-temporal region are rather more prominently produced downwards, and are rounded processes, overshadowing the group of foramina for nerves and vessels at their bases behind.

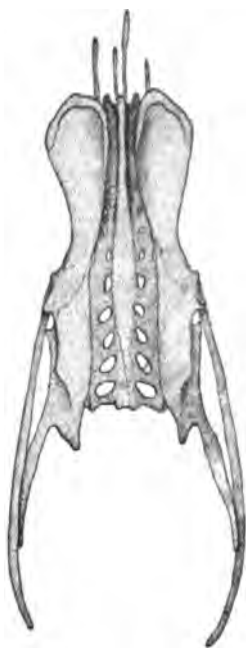


FIG. 3.—Pelvis of *Cephus grylle*, seen from above (specimen 16,776, Smithsonian Collection); life size.

The condyle is small, circular, and sessile; sometimes it shows a faint notch above. Its base, in common with the periphery of the foramen magnum, lies nearly in the horizontal plane; the latter is large and usually sub-circular, though nearly a transverse ellipse in some specimens of *Lunda cirrhata*.

Puffins all have very large and peculiarly formed sclerotal plates fortifying fully one-third or more of the anterior part of the eyeball. Their arrangement is seen in Plate VII. fig. 15. They range in number from fourteen to eighteen, and have all

their edges finely serrated. Some little difference exists in their form for the various species; in *L. cirrhata* they are generally flatter than in *Fratercula*.

These Sea Parrots have a powerful mandible, of a form peculiar to themselves (Plates VI. and VII.). Beyond the articular ends the ramal sides are very deep from above downwards. One or two small foramina make their appearance in the surangular, but the foramen of the ramus is closed in by the dentary and splenial. Anteriorly the superior margins are sharp, whereas behind, like the inferior ones, they are rounded. A small process is seen at the symphysial apex anteriorly, and a small convex rise in the ramal border on either side of it.

Below and anteriorly these ramal borders are convex downwards, and gradually approach each other as they pass forwards and upwards, until they meet in the posterior termination of the true symphysis nearly half way up the ascent. Between the ramal walls above this the bone is longitudinally scooped out to the upper termination of the symphysis.

The coronoid processes are but feebly developed, and the angles have sharply recurved processes, as in all other *Alcidæ*.

A careful examination of a number of skulls of these birds leads me to think that air never gains access to the bones that compose them. I fail to find the usual pneumatic foramina in the mandible just described.

Reference has already been made to the hyoid arches of the Puffins, and I have figured these in Plate VII. fig. 16. It will be seen that the basi-branchials anchylose together, and that the cerato-hyals are ossified alone in the anterior arch.

Epibranchials in young specimens are sometimes entirely in cartilage, and even in birds nearly mature only the anterior and posterior ends of these parts are ossified, the rod intervening remaining in cartilage.

Of the Remainder of the Axial Skeleton in Puffins.
(Plate VIII.)

Aside from their long and slender ribs, the skeleton of the trunk in these Sea Parrots is notable for its strength and compactness. The vertebræ and sternum are large and strong, and the pectoral arch and pelvis are solid and thick the whole

impressing one with its general stability, which is in no way lessened when this part of the skeleton is completed by the addition of the massive skull described in the foregoing paragraphs.

We find the cup of the atlas perforated by the odontoid process of the second vertebra, and its neural arch broad, with thickened postero-external angles.

The neural spine of the axis vertebra is a largely developed tubercular process. Substantial processes are also reared above the postzygapophyses in this segment, while below we find considerable of a hypapophysis. In all these respects the third vertebra agrees with the axis, but the processes are not quite so thoroughly developed, except the last one. In the fourth vertebra the neural nearly, and the processes above the postzygapophyses quite, subside, while the pre- and postzygapophyses are themselves connected by a delicate bony bar. The lower spine still persists in both of them. Commencing with the third vertebra, the par- and pleurapophyses are short and spine-like throughout the series, until we arrive at the fourteenth vertebra, where they constitute the first pair of free ribs. The lateral canals which they inclose are of good calibre, being above the average in point of size. Only the seventh and eighth vertebræ may be modified to protect the carotid arteries by developing open canals at their under aspects, but in other specimens three, or even the sixth, seventh, eighth, and ninth, may be utilised to this end. Usually the succeeding vertebra bears a hypapophysis, to become a broad median one in the next (the tenth), whence it is continued from before backwards to include the nineteenth, being strong and bicornuate from the fifteenth towards the pelvis.

The twentieth and twenty-first are without it, these being the ultimate free vertebræ of the dorsal region. The *fifth* cervical vertebra develops strong tuberos transverse processes that stand directly outwards from the sides of the prezygapophyses, and these are to be found well developed on all the succeeding vertebræ till we reach the pelvis. They are flat in the dorsal region, and bear metapophyses. In the fifth vertebra we also miss the neural spine, and it does not make its appearance again till the fourteenth, while after it we find the usual pattern of dorsal spines interlaced with spiculæ of bones.

Through the cervical region the neural canal is cylindrical, and not particularly well protected behind by the somewhat narrow and spreading pre- and postzygapophyses.

The articulations among the centra of the dorsal region have lost their opisthocœlian character, and are now more of the heterocœlous type.

In these Sea Parrots the entire skeleton seems to be non-pneumatic, as in the *Spheniscomorpha*. Suspended from the fifteenth vertebra we find a pair of fully developed ribs, with free extremities, though bearing epipleural appendages articulating with their posterior borders. These ribs are shown in Plate VIII., where the series begins with the fourteenth vertebra.

The first pair of ribs reaching the sternum through their hæmapophyses come from the sixteenth vertebra, from whence they are found on each dorsal segment to include the twenty-first, having all the characters of these bones in the Auks generally. A slender pair, with immensely long hæmapophyses, are also attached to the under side of the pelvis. These, and the pair of dorsals that proceed from them, rarely have epipleural appendages, but the last sacral pair may have their hæmapophyses reach the sternum either in *Fratercula* or *Lunda*. When this happens there are seven facets on each costal border of the sternum, otherwise only six, which must be considered the rule.

Regarding the pelvis from a superior view, I think we must confess that it would be hard to find or to create a better intermediate form of this bone, to stand in the series connecting two such types of it as are found in the skeletons of *Alca*, and, say *Cepphus grylle*. The pre- and postacetabular areas are subequal, the latter being rather the more extensive. Anteriorly the borders of the ilia are rounded and faintly emarginated. Their sides, back as far as the cotyloid cavities, look more and more outwards, and are uniformly concave. The inner borders of this part of the iliac bones may or may not convert the ilio-neural grooves into ilio-neural canals by reaching the summit of the united neural crest of the dorso-lumbar vertebræ of the sacrum, though they usually do. The neural crest subsides on the hinder half of the sacrum entirely, while on either side of

the flattened top of the united neural arches in this situation we find the foramina between the transverse processes forming a double row down this part, as is common among the *Alcidae*.

We are to note upon a lateral view of this pelvis its general resemblance to the bone as we found it in other Auks. Here, however, we may occasionally find that the obturator foramen is thoroughly divided from the obturator space by a bony bridge. This is not shown in Plate IX., which was drawn from a specimen where it did not happen to occur; I find it perfect in a specimen of *F. corniculata*, No. 13,652 of the Smithsonian Collection.

As usual in the *Alcidae*, a notch occurs between the ilium and ischium on the posterior border, the latter bone being produced backwards to a considerable degree, to end in an inturned pointed extremity.

Each postpubis is strong and powerfully produced; they sweep far behind, and are gently incurved throughout, their tips being finished off in cartilage to almost meet behind.

From the twenty-second to the thirty-fourth vertebra inclusive are commonly united in the sacrum of the pelvis, the ilia being firmly anchylosed to them in the usual manner. The first five, rarely six, of these throw out their processes against the inferior iliac walls; the ultimate five do likewise, but the intermediate three have their processes aborted. The diapophyses of the tenth are more massive than either those in front or behind them, and their ends are expanded, abutting against the bone between the cotyloid ring and ischiac foramen, adding additional strength to these parts to support the pelvic limb.

Lunda cirrhata may have as high as *ten* free vertebræ in its tail, with an elongated pygostyle containing several more (No. 13,656).

They seldom seem to fall below eight in any of these Sea Parrots.

This number of caudal vertebræ even exceeds the number found by Marsh in the extinct *Hesperornis*, which had but nine free ones, and three in its pygostyle.

The neural canal passes through this whole series in *Lunda*, gradually diminishing in size. More or fewer of the first ones have anteriorly bifid, stumpy, neural spines, and, from the first

to the fourth inclusive, the diapophyses become rapidly shorter and more depressed. After that they increase in size to include the eighth, to be smaller in the ninth, and nearly aborted in the tenth.

The articulating surfaces of the centra on the vertebræ are nearly flat, and of a uniform outline with the convexity below.

Upon the tenth to the fifth chevron bones occur, becoming gradually smaller as we proceed in that direction forwards.

If the length of the skeleton of the tail of a bird, or the number of vertebræ it may contain, is any indication of its low position in the scale of organisation, then these Puffins certainly belong to that category.

A coracoid of the *pectoral arch* is an exceedingly strong and heavy bone. Its head hooks forwards to make the usual articulation, seen in the Auks generally, with the clavicle. Its scapular process is broad, and extends well down upon the shaft. So far as I have seen, it is always perforated by the foramen alluded to when speaking of this bone in other forms. The shaft is straight, and convex from side to side anteriorly, its upper half being flat behind, moderately concave below on the same aspect.

Its articular base is very broad from before backwards, and the inner and outer angles are modified as processes, the outer ones to fit in a socket, on either side, found at the anterior base of each costal process of the sternum.

This arrangement tends to retain the coracoid in its sternal bed, and lessen the chances for dislocation of the bone. The inner processes offer a thin edge above for the insertion of that ligament, which descends from the inferior border of the scapular process, present in this Puffin, as in nearly all of the class.

Those processes found so prominent in the Murres at the lower externo-lateral margins of the coracoidal shaft are here barely large enough to attract attention.

The glenoid cavity of these birds is comparatively small, but both the coracoid and scapula offer the usual proportionate share of surface in forming it.

The blade of a *scapula* has the usual form; here its posterior third, however, is broader than the remaining two-thirds,—and is not truncate, simply having its end rounded off. Its head is

broad transversely, compressed from above downwards, and in other respects agrees with the genus *Simorhynchus*. The furcula is a notably large and U-formed bone. Its limbs are generally narrow and compressed from side to side. From head to the small hypocleidium they curve backwards and bear the relation to the other bones as shown in Plate VIII. Further, each head is elongated as in all Auks, and the facets on their outer sides for the coracoids are nearly as large as those figured by Owen for *Plautus impennis*.

Puffins have a *sternum*, as I have already said, profoundly characterised by all the features that pertain to the fundamental type of this bone as it is now found in existing *Alcidae*.

In general form it may be said to even agree with the same bone in such an Auk as the Razor-bill, having its keel of the same shape, but bearing in addition a broad ribbon-like strip along its entire lower margin. This overhangs the blade of the keel proper, and spreads out behind upon the mid-xiphoidal portion of the sternal body that is found posterior to where the carina terminates. It is comparatively broader anteriorly, and still more so posteriorly, than the sternum of *Alca*, and it is this posterior half of the body where the greatest amount of difference occurs in the

two birds. Above, this is shallowly concave, being in gradual continuation of the more pronounced concavity of the anterior portion. Upon its pectoral aspect we observe the mid-xiphoidal extension beyond the point where the keel terminates. This sometimes is quite shield-shaped, having lateral angles, and suggesting the idea that they might meet the posterior apices of the lateral xiphoidal processes, and thus, in some rare cases, form foramina instead of the notches, as are seen in all the specimens at my hand.

This view is not supported, however, by a peculiarly formed sternum of *F. corniculata* in my hand. Here the shield-like form of the mid-xiphoidal extension is quite perfect, but the



FIG. 3A.—Antecubital aspect of left metacarpus of *Uria troile californica* (specimen 16,973, Smithsonian Collection); life size.

inturned tips of the lateral processes meet the sternal border above the angles of the shield (specimen No. 13,653 Smithsonian Collection).

The general plan, then, of this sternum is to have external notches and a small elliptical foramen within their internal borders. These latter are relatively larger in *F. corniculata*, but my material goes to show that they may be in any stage up to entire absence, though the outside notches are always present.

On this pectoral aspect the costal borders which support the six or seven hæmapophysial facets, on either side, project downwards quite prominently. Their anterior halves limit the muscular insertion, but posteriorly these pectoral lines run on to the body of the bone and terminate at about the same point posteriorly that the carina does.

The costal processes are more prominent than we found them in the *Alcina*, and the pits at their outer bases deeper, forming firm footholds for the coracoids.

Though much sunken, the manubrium is very broad transversely, being convex antero-posteriorly and marked by a shallow median groove. About its base, and all this anterior part of the bone supporting the articular surfaces for the coracoids, is very thick and massive, in striking contrast with the shell-like and broad expansion of the thin xiphoidal extremity.

Of the Appendicular Skeleton in the Puffins.

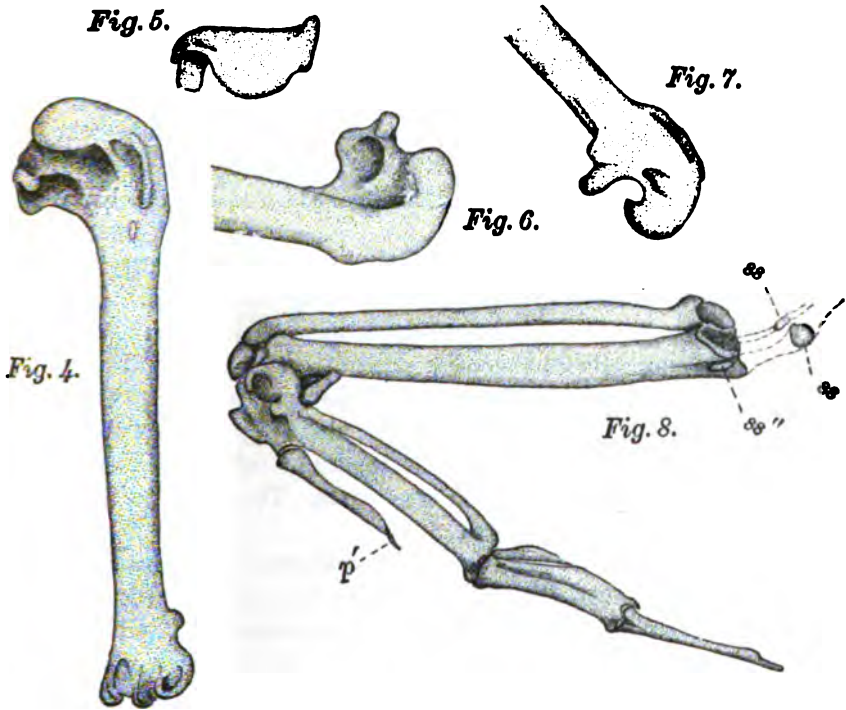
The Pectoral Limb (figs. 4 to 8).—Except for their difference in size, the pectoral limbs of *Lunda* and *Fratereula* agree with each other, even to their minor details, so that the description of one will answer perfectly well for the other.

The form of the *humerus*, again, approaches that of the Razor-bill and Murres, although it has some very well marked characters of its own. The ulnar crest is produced as a prominent outstanding process reared upon the ulnar margin of the pseudo-pneumatic fossa. It is separated from the humeral head by a deep valley, which opens into the general excavation upon the anconal aspect of the proximal end of the bone.

The articular head curls over this latter in such a manner as

to overshadow a deep recess, fully as well defined and far deeper than we usually find the pneumatic fossa in other birds.

This condition is very faintly marked in *Alca*, but constitutes a striking peculiarity in the humerus of the Puffins.



Various Bones of the Upper Extremity of *Lunda cirrhata* (specimen 1365c, Smithsonian Collection); life size.

FIG. 4.—Anconal aspect of right humerus.

FIG. 5.—Direct view of the end of its proximal extremity.

FIGS. 6 and 7.—Views of the same held in different positions.

FIG. 8.—Anconal aspect of bones of antibrachium and manus, &c.; right pectoral limb. *p*, claw on pollex; *ss*, *ss'*, *ss''* are sesamoids about the elbow. The dotted line represents the tendon, and these bones are here shown in their normal position; *ss''* is the usual sesamoid.

The radial crest is bent clear over to the palmar side, and is thick and tuberos. A well-marked pit denotes the point for the insertion of the deltoid muscle, as in *Alca* and others.

Although not quite as much compressed as in the Razor-bill, the shaft of the bone is sufficiently flattened in a similar

manner as to attract our attention upon a very superficial examination of it, and more in comparison than it is in *Simorhynchus*.

An ectocondyloid tubercle of fair dimensions occupies its usual site, on the border of the shaft, just above the oblique tubercle. This distal extremity of the bone is fashioned almost exactly as we find it in the Auks proper, agreeing entirely with such a form as *Alca torda*.

Ulna and radius are also flattened nearly as much as the corresponding bones in the Razor-bill Auk, and their form agrees with them even better than the bones of the brachium does.

The shaft of each is nearly straight, which contracts very much the interosseous space when they articulated. The rounded borders of the bone are upon this aspect, and the sharp ones opposite them on the other side of the shaft.

The structure of the proximal and distal ends of these bones of the antibrachium requires no special description here, as it could be nothing more than a repetition of what I have already said of these bones in true Auks. They seem to agree even in their minor details.

As already stated there are *three* sesamoids about the elbow in these Sea Parrots. They have been accurately represented in the figures in the exact positions they occupy in life, and they are a constant character in adult forms of the three genera *Simorhynchus*, *Fratercula*, and *Lunda*.

The *ulnar sesamoid* I have found in numbers of specimens in all of these. It is generally intermediate in size between the two sesamoids in the tendons at the elbow proper.

No special description is required for the two usual segments found in the carpus; though differing slightly in form, they are essentially the same as in the *Alcinæ*.

In *Manus* we find a minute claw at its distal apex; the last phalanx of index is longer than pollex digit, and without any such structure at its extremity.

Of the Pelvic Limb (figs. 9 to 13 inclusive).—As with the pectoral extremity so with the present one, it essentially is alike for the two genera of Puffins, *Fratercula* and *Lunda*. As we found to be the case with the thigh-bones in the Auks, the

trochanterian ridge of the femur is nearly on the level with the articular surface of the summit, it only being for a short distance down the antero-lateral aspect of the shaft that the trochanter major makes any show of a crest. In the figure the bone is turned so that it appears higher than it would if held otherwise. The head of the bone is globular, and its neck makes an angle with the shaft. This latter is quite straight and subcylindrical in form.

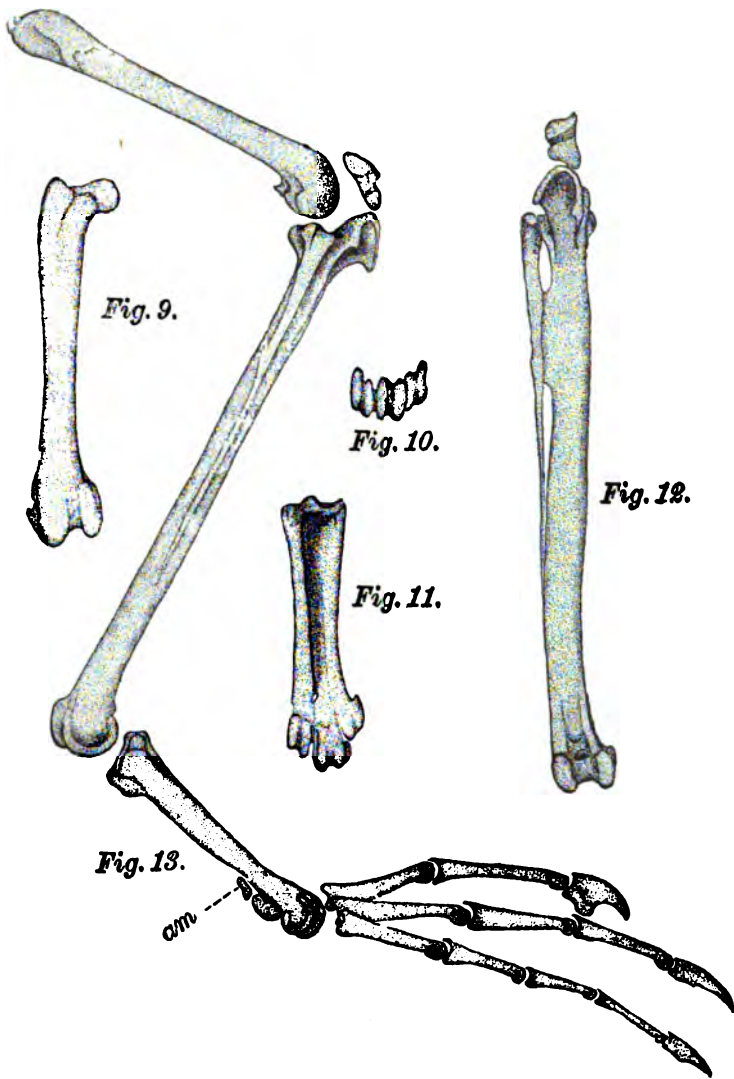
Although the condyloid extremity is shaped as in most birds, it has here a peculiar cant towards the inner side, which makes the external condyle appear rather lower than it really is, it being the lower of the two.

The inner condyle is considerably flattened on its posterior aspect, and completely covered by the articular surface for that part of the summit of the tibia which it meets in articulation, thus constituting the peculiar obliquity to the mechanism of this point common to most pygopodine birds. The *tibia* also assists in this by having its head slightly bent towards the outer side. In the present form, however, this is not participated in by the fibula. Figure 12 is a direct anterior aspect of these bones, and this feature is not as evident as when they are slightly turned. Sections of the shaft of the tibia are elliptical in outline, the long axis being placed transversely, and the lower half of this bone is gently curved inwards, so that the line on the fibular side is convex from above downwards, the reverse being the case on the opposite side.

At the proximal end the pro- and ectocnemial ridges are formed much as we found them in the Murres and others, though the apex of the cnemial process is more rounded off. It is surrounded by a patella as in *Alca*, but a better developed one, having, as in the Penguins, an oblique groove across its anterior surface for the ambiens muscle. I have reason to believe that this bone ossifies from two centres.

Returning to the distal end of tibia, we find the usual bony bridge spanning the tendinal grooves directly across.

The condyles are constituted as in the Auks, in all respects. The fibula articulates as usual with its ridge at the outer tibial aspect. This is done in such a manner that its shaft projects behind, and is rather retreating in front. Below, its slender



Various Bones of the Right Pelvic Extremity of a *Lunda cirrhata* (specimen 13,656, Smithsonian Collection); life size.

FIG. 9.—Anterior view of the femur.

FIG. 10.—The tarso-metatarsus from below.

FIG. 11.—The tarso-metatarsus, anterior view.

FIG. 12.—Anterior view of tibia, fibula, and patella.

FIG. 13.—Outer aspect of the entire right pelvic extremity; *am*, a free and rudimentary accessory metatarsal.

length merges into the shaft of tibia-tarsus, and were it produced downwards it would reach a point at which the oblique ligament is inserted on the antero-external aspect.

The tarso-metatarsus is a broad, short, and thickset bone. At its summit are the two articular concavities for the condyles of tibio-tarsus. Between them, anteriorly, stands on the margin a convex tubercle to pass into the intercondyloid fossa of this leg bone. The outer one encroaches slightly upon the shaft in front, while the inner one has its outer margin tilted upwards.

Both pierced and grooved, the hypotarsus is broad and flat but does not extend down the shaft in any form whatever, as we sometimes find it in birds. Anteriorly the shaft of tarso-metatarsus is longitudinally grooved for its entire length, while posteriorly it is very slightly so. Transversely it is very broad in comparison with its antero-posterior thickness. We might say that it is of pretty uniform width anywhere across its anterior face, and about twice as wide as it is thick, through and through. It is pierced below by the usual foramen, and the trochlear extremities are constructed as in the Auks, in *Uria* for instance. Normally, some of the tendons may ossify at the back of this bone, as they pass it in their descent to the foot; but in addition to this, we find a subelliptical rudimentary bone occupying the position of the accessory metatarsal and attached to the shaft in the same manner by ligament (fig. 13, *am*).

In the figure just referred to, it will be seen that the joints of the podal digits are in no way peculiar, beyond the extraordinary thickened claw of the inside toe. The distal trochlea of the phalanx which articulates with this is so modified, a modification that is coaptly responded to on the part of the claw itself, as to permit the enlarged and abruptly curved latter joint to turn its base to the outer side and lie nearly flat in the horizontal position. It would be difficult to explain or fathom the original cause for such a modification as this, or even guess at its present utility, and in the light of our present knowledge of the physiology of such structures, I expect it must be consigned, *nolens volens*, along with many other such freaks, to the category of the yet inexplicable.

This completes my work, so far as the osteology of the *Alcidæ* is concerned, with the exception of an analytical synopsis of the characters of the group. It is my intention to submit this here, and in doing so, I will aim to select the most prominent and constant characters found in the skeletons of all the North American *Alcidæ* that I have been enabled to investigate, and more particularly those that I trust will be useful hereafter in determining the affinities of the several species, and aid in their classification when their structure comes to be still more fully known.

As the typical forms of existing North American *Alcidæ* are not numerous, and the list in my hand not quite complete, I will arrange under the head of each character, when it is deemed advisable and the material admits of it, those Auks in which it appears, and on the other hand those in which it is absent. After they have been thus contrasted, we will have something to say about our conclusions.

*Analytical Synopsis of the Osteological Characters of the
North American Alcidæ.*

1. Superior mandible, with anterior portion elevated, convex, prominent, laterally compressed, and cultrate, terminating in a sharp hook (*Alca torda*, *Fratercula arctica*, *Fratercula corniculata*, *Lunda cirrhata*).
2. Same character, but the superior mandible not hooked. (*Cyclorrhynchus psittaculus*).
3. Superior mandible tapers gradually to a point, culmen roundly convex and not modified (*Synthliborhamphus antiquus*, *Brachyrhamphus marmoratus*, *Cepphus grylle* (the genus *Cepphus*), *Uria troile* (the genus *Uria*), *Uria lomvia arra*).
4. Same, but the superior mandible broad at base, and shortened (*Simorhynchus cristatellus*, *Simorhynchus pusillus*, *Ptychorhamphus aleuticus*).
5. Supraorbital glandular depressions entire, the upper orbital rim being finished off with an osseous emargination. Crotaphyte fossæ either reaching the supraoccipital prominence or encroaching upon its summit (*Alca torda*, *Uria* (all the species)).

6. Supraorbital glandular depressions not entire; upper orbital rim absorbed, producing wing-like post-frontals (*Fratercula*, *Lunda*, *Simorhynchus*, *Ptychorhamphus*, *Synthliborhamphus*, *Brachyrhamphus* (crotaphyte fossæ lateral), *Cepphus grylle*).

We must note here that the interorbital septum and anterior wall of brain-case is more or less deficient in all the *Alcidæ*, being completed by the soft parts. But this deficiency varies so with age and other circumstances, that it becomes thoroughly unreliable as a character. Again, we find, in such a form for instance as *C. pitraculus*, the maxillo-palatines nearly horizontal, whereas in *Lunda* they are nearly vertical; all angles assumed by them are found between these two genera, *Alca* and *Uria* about holding a 45° position. Similar intergrading obtains with the vomer. In *Alca* and *Uria* it is never produced as a spine in front, while this is its normal condition in *Simorhynchus* and the Auklets generally. The *Fraterculinæ* seem to waver in this particular, its anterior extremity sometimes approaching first one and then the other extreme type.

The mandible, although varying not a little throughout the group, in its general form, presents in all the same fundamental characters. The angle is always recurved, the surangular is pierced by one large foramen, or two small ones; the ramal vacuity is usually closed by the splenial or dentary, and the sides of each ramus are more or less vertical, and the symphysis comparatively short. It is V-shaped viewed from above.

As a rule the *Alcidæ* seem to have the first pair of small free ribs on the fourteenth vertebra followed by a better developed free pair on the fifteenth. Both *Brachyrhamphus* and *Synthliborhamphus* form a singular exception to this rule; their first free riblets occurring in the thirteenth vertebra.

Before recording this as a constant character, I would prefer to examine additional material and other Murrelets. It is the case in the two alcoholic specimens before me.

Likewise, the number of ribs reaching the sternum by hæmapophyses varies, this variance depending upon the greater number of posterior pairs.

But the ribs are evidently on the decrease as we pass from

the Auks and Auklets to the Puffins; for instance, *Alca torda* has *nine* pairs posterior to the first two free pairs, eight of which articulate with costal ribs, and they become very long and sweeping behind.

Now, *Lunda cirrhata*, as a rule, has but *seven* corresponding pairs, and only six of these articulate with costal ribs; and they are comparatively shorter and less sweeping.

The pelvis offers us no definite characters that can be relied upon as constant, beyond the gradual change in its form, and this will be duly considered hereafter. It is long and narrow in *Plautus*, *Alca*, and *Uria*, to become shorter and more spreading posteriorly as we pass to other genera.

The number of free caudal vertebræ range from seven to ten, not including the pygostyle. I have found the latter number in a specimen of *Lunda cirrhata*.

7. Those in which the sternum, if notched, is 1-notched on either side, though the forms here arrayed may have their sterna showing the various stages approaching this condition all the way from a single small foramen on one side only (*Uria*) to the type pattern. Sternal body long and narrow (*Alca*, *Uria*, *Synthliborhamphus antiquus*, *Brachyrhamphus marmoratus*).

8. Those in which the fundamental pattern of the sternum is a single notch on either side, and a single small foramen within its inner border.

Sternal body rather broader anteriorly and more spreading behind (*Cepphus grylle*, *Cepphus columba*, *Lunda cirrhata*, *Fratercula arctica*, *Fratercula corniculata*).

9. Those in which the fundamental pattern of the sternum is long and narrow (varies for the species), with xiphoidal extremity much produced beyond the carinal termination, swelled, concave above, and with one large, oblique, elliptical *foramen* on either side.

The genus *Simorhynchus*.

For the presence or absence of the claw upon the pollex; the number of sesamoids about the elbow, the characters of the tarso-metatarsus, and many other minor details, I prefer to examine additional material before offering them as constant characters. Due weight will, however, be given to such facts as

the constancy of three sesamoids about the elbow in the Sea Parrots, the free bone at the site of the accessory metatarsal, and their claw upon pollex phalanx.

Conclusions.

Regarding the *Alcidæ* as a group by themselves, aside from any kinship they may have with other groups, evidently related, as for instance the *Laridæ*, the *Procellariidæ*, or more remotely the *Urinatoridæ*, my studies prompt me to offer the following suggestions as to some of the probable affinities of the several forms thus far considered. Further on, I will again review what I say here in the light of our examinations of the osteological material illustrating the Gulls, Albatrosses, Petrels, and others.

Of the position of the subfamily *Allinæ*, I can say but little or nothing, though I enter the suspicion here, that I am inclined to believe that this little Dovekie will, when its structure has been carefully studied, be found to be more nearly related to the Auklets than has been generally supposed.

Of the three genera of the *Alcinæ*,—*Uria*, *Alca*, and *Plautus*,—I am of the opinion that *Uria* is the highest type of the group, and most nearly related to the *Laridæ*. On the other hand, *Plautus impennis* is the most lowly organised of the *Alcinæ*, and should be awarded a position in accordance.

In other words, I think the Auks and Murres as they now stand in the *A. O. U. Check-List*, is a very well chosen group, though the Great Auk should be placed where the genus *Uria* now stands, exhibiting, as it does in its skeleton, certain affinities with the Loons; while, on the other hand, *Uria* should occupy the place now awarded to *Plautus*, as a study of its skeleton and general structure points to the fact that it is more closely related to the Gulls than either *Alca* or *Plautus*.

So far as my osteological studies of the *Phalerinæ* go, they fully support the classification at present adopted by the Union, as set forth in the *Check-List*, for that subfamily, to the extent of the actual grouping proposed.

I am rather inclined to think, however, that these Auklets, Murrelets, and Guillemots came away from the ancestral Alcidine stock after *Plautus* did, and that the genus *Cephus*, as with

Uria, is probably more Laridine in its organisation than the Great Auk was.

However well we might picture such a branching in our mind, it would be almost impossible to demonstrate it diagrammatically upon paper, much less make it clear by any arrangement we might adopt in a tabulated Check-List.

There is no question as to the right of admission of the Puffins into the *Alcidæ*, and perhaps the creation of the genus *Lunda* will prove to be a warranted step. And notwithstanding the fact that both these Sea Parrots and the Auklets are known to shed at times certain horny coverings to their beaks, I must see in the skeleton of *Uria* certain characters, as the form of pelvis and pattern of sternum and others, a nearer approach to *Lunda* (and perhaps still nearer to *Ceratorhina*?) than is attained by the more alienated genus of *Simorhynchus*. On the other hand, we have, as militating against this, the evident resemblance of the skull of *Uria* to the skull in the Murrelets, and the partial encroachment of the feathers upon the nasal fossæ in the former, whereas these pits are remote from the feathers in *Simorhynchus*, one of the external characters upon which ornithologists have placed this genus among the *Phaleridinae*.

Where forms are as nearly related as some of these *Alcidæ* are to each other, and where some have retained their originally acquired osteological characters, whereas in others they have been suppressed, it becomes exceedingly difficult to divine the correct inter-relationship existing among them; but I believe what I have pointed out in the foregoing paragraphs is as near the mark as our present knowledge of the morphology of the group will permit. Much light will be thrown upon the matter when other parts of their anatomy have been investigated and compared, and the osteology of *Alle alle* and *Ceratorhina monocerata* is brought to our assistance.

When these conclusions were written, the *Check-List of the American Ornithologists' Union* had not been published, and I was ignorant of any changes the committee had in view in the classification of the water-birds. Indeed, I was many thousand miles away, and was principally guided in my notions of the taxonomy of the groups by Coues' "Key" (2nd edition), so

that, when the *Check-List* came into my hands, I was more than gratified to find that the rearrangement of the forms, whatever may have guided that committee in its final decisions so far as the taxonomy was concerned, agreed so completely with what my studies of the skeletons of those birds led me to suspect and record. It will be seen further on that these remarks apply with equal pertinence to some of the other groups.

It meets my purpose best, in the next Part (VI.), to consider the characters offered us in the osseous system of the *Diversa*.

EXPLANATION OF PLATES VI., VII., VIII.

Fig. 1. Skull of *Fratercula arctica*; right lateral view; life size; by the author, from specimen 16,994 of the Smithsonian Collection.

Fig. 2. Skull of *Fratercula corniculata*; right lateral view; life size; by the author, from specimen 13,655 of the Smithsonian Collection.

Fig. 3. Skull of *Lunda cirrhata*; right lateral view; life size; by the author, from specimen 13,656 of the Smithsonian Collection.

Fig. 4. Skull of *Simorhynchus cristatellus*; superior view; mandible removed; life size; by the author, from specimen 11,176 of the Smithsonian Collection.

Fig. 5. Skull of *Cyclorhynchus psittaculus*; superior view; mandible removed; life size; by the author, from specimen 13,649 of the Smithsonian Collection.

Fig. 6. The vomer of *Cyclorhynchus psittaculus*, seen from below; from the skull shown in fig. 5; life size; by the author.

Fig. 7. Skull of *Fratercula corniculata*; posterior view; mandible removed; life size; by the author, from specimen 13,653 of the collection at the Smithsonian Institution.

Fig. 8. The mandible of *Cyclorhynchus psittaculus*; viewed from above; life size; from the specimen, as shown in fig. 310; by the author.

Fig. 9. Skull of *Cyclorhynchus psittaculus*; right lateral view; life size; from specimen 13,649 (same as fig. 5) of the collection at the Smithsonian Institution; by the author.

Fig. 10. Skull of *Simorhynchus pusillus*; left lateral view; life size; by the author, from specimen 12,665 of the Smithsonian Collection.

Fig. 11. Skull of *Simorhynchus pusillus*; superior view; mandible removed; life size; by the author, from specimen 12,665, Smithsonian Collection (see fig. 10).

Fig. 12. Skull of *Cepphus grylle*; left lateral view; by the author, from specimen 16,776 of the Smithsonian Collection; life size.

Fig. 13. Skull of *Fratercula arctica*; superior view; mandible removed; life size; by the author, from specimen 16,994, Smithsonian Collection.

Fig. 14. Mandible of *Fratercula arctica*; viewed from above; life size. Specimen 16,994 (see fig. 13).

Fig. 15. Form of the eye in *Fratercula corniculata*, as preserved and shown by the sclerotal plate and sclerotic; natural size; by the author; specimen 13,654, Smithsonian Collection.

Fig. 16. Hyoid arches of *Fratercula corniculata*; from below; life size; specimen 13,655 of the Smithsonian Collection.

Fig. 17. Skull of *Fratercula arctica*; basal view, with mandible removed; life size; by the author, from specimen 16,994, Smithsonian Collection. Same specimen as fig. 13.

Fig. 18. Skeleton of the trunk of *Lunda cirrhata*; right lateral aspect; life size; by the author, from specimen 13,656 of the collection in the Smithsonian Institution.

THE PROPORTION OF BONE AND CARTILAGE IN
THE LUMBAR SECTION OF THE VERTEBRAL
COLUMN OF THE APE AND SEVERAL RACES
OF MEN. By D. J. CUNNINGHAM, M.D., *Professor of
Anatomy in Trinity College, Dublin.*

WITH the assumption of the erect attitude, the bodies of the vertebræ in the human spine, as well as the intervening inter-vertebral discs, have undergone considerable modification. In no part of the column is this more evident than in the lumbar region, upon which the greater part of the weight of the trunk and upper limbs has fallen. Among other changes the bodies of the lumbar vertebræ have become shortened and broadened out so as to widen the pillar of support.

In the majority of the quadrupeds¹ the bodies of the lumbar vertebræ are long, narrow, and rod-like; in Man they are short, broad, and disc-like. And it is interesting to observe that the transition from the one form to the other is not sharp and sudden, but can be traced, as a gradual process, step by step, through the Apes, in which the long axis of the spine is placed at a greater or less degree of obliquity in the different forms.

A consideration of these facts led me some time ago to believe that similar differences in the relative length of the lumbar vertebræ, although to a less degree, might possibly be present in certain of the more widely-separated races of man, and in a paper recently published in the *Proceedings of the Royal Society* I alluded to the subject, and gave some measurements bearing upon the question.² The number of specimens at my disposal at that time, however, was so limited that I was not able to speak with any degree of emphasis upon the matter. Since then, through the kindness of Professor Flower and Professor Chas. Stewart, I have had an opportunity of examining the fine collection of skeletons in the British Museum and in the Museum of the Royal College of Surgeons in England. This has confirmed me in the views which I had tentatively put

¹ In the elephant the bodies of the lumbar vertebræ are short and disc-like.

² "The Spine of an Australian Girl," *Proc. Roy. Soc.*, vol. xlv.

forward in the paper to which I have referred, and I now propose to deal with the evidence in detail.

The method which should be employed in measuring the vertebræ was a question which required some consideration. Aeby,¹ who has compared the amount of bone and cartilage in the spine of the European at different periods of life, measured the vertical depth of the vertebræ and the intervening discs along the anterior face of the column. This plan no doubt is suitable where we are dealing with one race and do not intend to carry our investigations lower in the scale than Man. But for the purpose which we have in view at present it is obviously impracticable, because the anterior and posterior vertical diameters of a vertebral body are greatly influenced by subsidiary circumstances, such as the habits of the individual and the character of the spinal curvature. With this in view, I therefore determined to measure the bodies of the different lumbar vertebræ along the axial line of the spine, or, in other words, from the central point of the upper surface to the central point of the lower surface. The second measurement was made in the sagittal direction, from the centre of the posterior surface to the centre of the anterior surface. In this way, the epiphysial bulging at the upper and lower ends of the vertebral body were avoided. The two measurements thus obtained may be distinguished as the *vertical* and the *sagittal*.

For the purpose of comparing the results obtained by these measurements, and striking an average for the different apes and races of men under consideration, it is necessary to construct an index for each vertebra and also for the sum of the vertebral measurements in a given individual. In calculating such an index, the sagittal diameter may be taken as the standard and equal to 100. The index for an individual vertebra can be determined as follows:—

$$\frac{\text{Vertical diameter} \times 100}{\text{Sagittal diameter}}$$

Then the combined index which gives expression to the condition of the group of vertebræ under consideration in a particular individual may be obtained thus:—

¹ "Die Altersverschiedenheiten der Menschlichen Wirbelsäule," *Arch. f. Anat. und Entwickl.* (His und Braune), 1879.

$$\frac{\text{Sum of the vertical measurements} \times 100}{\text{Sum of sagittal measurements}}$$

The result arrived at by the latter calculation may be termed the *Lumbar Sagitto-vertical Index*.

In a vertebra, then, which presents an index of 100, the sagittal and vertical diameters of the body are equal; when the index is 100+, the vertical diameter exceeds in length the sagittal diameter; and lastly, when the index is 100—, the vertical diameter is shorter than the sagittal diameter.

The following Table gives the general results, which have been obtained by the measurements. In the Gorilla, Chimpanzee, and Orang, which possess only four lumbar vertebræ, and in the lower Apes which possess six or seven, the five lower true vertebræ have been held as equivalent to the five lumbar vertebræ in Man.

Table I.

	APE.						MAN.				
Five lower true vertebræ.	1 Macacus rhesus.	1 Macacus nemestrinus.	1 Baboon.	7 Gorilla.	11 Chimpanzee.	9 Orang.	20 Andamans.	9 Australians.	4 Negroes.	19 Europeans.	5 Natives of India.
I.	141.1	118	85.7	94.6	89.6	76.7	95.7	92.7	98.6	84.3	84.8
II.	126.3	126.6	95.6	100.4	88.7	86.3	90.8	89.8	86.3	83.9	79.2
III.	144.4	126.6	100	98.2	86.6	85.8	86.5	82.2	86	78.4	75.1
IV.	119	126.6	104.5	105.6	86.8	87.5	81.4	78.5	77.6	74.8	74.2
V.	100	117.4	109.5	126.8	93.5	93.3	80	76.5	71.2	73.7	72.2
Lumbar sagitto-vertical index,	126.2	122	99.1	105.1	89	85.7	86.3	84	82.9	79	77.1
Percentage of Cartilage in Lumbar Section of Column, .	1 speci- men.	1 speci- men.	1 speci- men.	...	3 speci- mens.	1 speci- men.	...	1 speci- men.	...	4 speci- mens.	...
	16.6	19	19.3	...	23.9	27	...	30.6	...	35.7	...

In many quadrupeds the vertical diameter of the body of a lumbar vertebra is considerably greater than twice the length of the sagittal diameter, and in several of the lower forms of Ape (*Cercopithecus*, &c.) it is about twice the length. None of these,

however, have been introduced into the above Table. Only those in which the vertebral bodies have undergone a certain amount of shortening are dealt with. In the Chacma Baboon the two diameters are very nearly equal. The index is 99·1, and, therefore, on antero-posterior section the vertebral bodies present a square outline. In the Macaque the vertebral body is a good deal longer; the *rhesus* gave an index of 126·2, and the *nemestrinus* an index of 122.

In the Chimpanzee, and more especially in the Orang, there is a sharp and decided fall in the relative length of the bodies of the lumbar vertebræ, the index for the former being 89, and for the latter 85·7. The Gorilla differs widely from these in presenting an index of 105·1, and thus exhibiting a condition of the vertebral bodies which approaches that of the lower Apes. It is difficult to account for this peculiarity in the Gorilla. Only seven specimens were examined, and the general index was a good deal affected by two circumstances, viz., an exceedingly high index presented by two specimens, and the great length of the body of the last lumbar vertebra in all the specimens in which it was measured. The two specimens to which I refer gave an index of 114·5 (a male) in one case, and 130·4 (a female) in the other. But even excluding these, and calculating the general index from the remaining five spines, the result would still reach 97·6. The great length of the body of the last lumbar vertebra in the Gorilla is, indeed, a marked peculiarity. The indices obtained for this vertebra in four specimens were—113·7, 118·6, 134, 155·5. In the remaining three spines the last lumbar vertebra was fused to the sacrum, and could not be measured. For these three vertebræ, therefore, an average derived from the other four had to be struck. Of course, an average obtained in this way for three out of thirty-five bones cannot affect the general statistics much; but still we cannot regard the figures as possessing the same value as in the case of the Chimpanzee and Orang, in which each individual bone was measured.

If we turn now to that part of the Table which deals with some of the races of Man, we find that here also marked differences exist in the relative length of the bodies of the lumbar vertebræ. They are longest in the Andamans, who possess an index of 86·8. This exceeds the index obtained for the Orang,

but falls short of that of the Chimpanzee. The Australians present an index of 84, the Negroes an index of 82·9, and the Europeans (composed of five French and fourteen Irish) an index of 79. A gradual but distinct shortening of the vertebral bodies, therefore, takes place as we pass from the Andamans to the Europeans. But the natives of India, five of whom I was able to measure, appear to possess vertebral bodies even shorter than those of the Europeans. The index afforded by them was 77·1.¹

When the indices of the individual vertebræ in the different groups are compared, a marked difference becomes apparent between those obtained from the races of Man and those from the Ape. In the higher Apes, and also in the Baboon, the bodies of the lumbar vertebræ increase in length from above downwards—in other words, the longest vertebra is at the bottom of the series, and the shortest at the top. In Man, however, exactly the reverse holds good. The longest vertebra is at the top of the series, and the shortest at the bottom. The Macaque does not conform to either of these rules, and the Chimpanzee does not show the condition so distinctly as the Gorilla, the Orang, and the Baboon.

In the human spine it is easy to account for the gradually increasing degree of flattening of the lumbar vertebræ from above downwards, because, in the fully-acquired erect attitude, the lower the vertebra is in the series the greater is the weight which it has to carry. In quadrupeds (*e.g.*, the Dog) I observe that the general tendency is for the length of the vertebral bodies in the lumbar region to increase slightly from before backwards.² In the light of this fact, therefore, we may conclude that, whilst the pressure to which the lumbar vertebræ of the Anthropoid Ape have been subjected has been sufficient to reduce them very considerably in length, yet it has not been sufficient to affect the lower members more than the upper members of the series.

¹ The difference between the Europeans and natives of India is not so marked as might at first sight appear. All the specimens of the latter which I examined were males; and if we compare the index obtained (77·1) with that of the European males (78·3, *vide* succeeding Table), there is only 1·2 of difference.

² The 7th or last lumbar vertebra is generally an exception to this rule in the Dog. It is shorter than those which immediately precede it.

Remarkable sexual distinctions are discovered when we contrast the relative length of the bodies of the lumbar vertebræ; and further, this is not confined to the different races of Man, but is also apparent in the Anthropoid Ape. The difference is so uniform and so manifest that it cannot be accounted for as a mere coincidence. The following Table gives the *lumbar sagitto-vertical index* in the two sexes:—

Table II.

	APE.						MAN.					
	Gorilla.		Chimpanzee.		Orang.		Andamans.		Australians.		Europeans.	
	Five males.	Two females.	Six males.	Five females.	Six males.	Three females.	Twelve males.	Eight females.	Six males.	Three females.	Ten males.	Nine females.
Lumbar sagitto-vertical index,	101·5	114·1	86·4	91·7	84·2	89·0	84·5	90·5	81·2	89·5	78·3	80·2

The sexual distinction is more marked in the Apes and in the low races than it is in the European, but in all cases it consists in a relatively greater length of the lumbar vertebræ in the female than in the male. As I have shown in a previous memoir, the entire lumbar column is proportionately longer in the female, and the condition of vertebræ brought out by the foregoing Table may be in harmony with this.¹ In the European the difference between the sagitto-vertical indices of the male and female is only 1·9; but in the Australians it is 8·3, and in the Andamans 6.

The lumbar region of the female spine, therefore, is fashioned upon a different plan from that of the male. It is relatively longer and it is more strongly arched; further, the bodies of the vertebræ are of greater relative length, and they are moulded more distinctly in adaptation to the lumbar curvature.² All these distinctions may be accounted for by the different habits pursued by the two sexes. There is no part of the vertebral column which is more readily moulded by the functions that

¹ In the female the lumbar region constitutes 32·8 per cent. of the entire column, in the male only 31·7 per cent.—“Cunningham Memoir, No. 2,” Royal Irish Academy.

² “Cunningham Memoir, No. 2.”

the spine has to perform, because it is that section of the column which works under the greatest degree of superincumbent pressure.

Age, as well as sex, influences the sagitto-vertical index of the lumbar vertebræ. I regret that I have had no opportunity of testing this aspect of the question, but any one who examines the mesial section of the vertebral column of a child, will observe the great relative length of the bodies of the lumbar vertebræ. They are almost baboon-like in their outline.

It is needless to enter into the individual differences which are present in connection with the lumbar sagitto-vertical index in the different groups under consideration. As an appendix to this paper, tables are given in which the index of each of the vertebræ in every individual examined can be studied.

If we turn now to the intervertebral discs which enter into the construction of the lumbar section of the spine, we find that, in so far as their depth is concerned, they bear a direct relation to the length of the vertebral bodies; the longer the bodies of the vertebræ the shorter are the cartilaginous discs.

In measuring the discs of cartilage, I have chosen, as in the case of the vertebræ, the axial line of the column, and, to ensure perfect accuracy, the spines were in the first instance frozen, and then divided in the mesial plane with a saw. No bulging of the soft pulpy interior of the discs was in this manner possible, and the full axial depth of each cartilage was accurately determined when still in the frozen condition. Of course, the method employed is one which only can be applied to a limited number of spines, and herein, perhaps, consists its defect. The figures which are given in Table I. have been obtained from one *Macacus rhesus*, one *Macacus nemestrinus*, one Baboon, three Chimpanzees, four Europeans, and one Australian. The percentage of cartilage in this section of the spine is obtained by comparing the sum of the axial measurements of the discs with the axial length of the lumbar column. The figures are very striking (see Table I.). As the bodies of the vertebræ shorten the amount of cartilage increases, so that if we compare the lumbar region of a European with that of a Macaque, we note that relatively there is twice as much cartilage in the former as there is in the latter. As the vertebral column has become gradually

Lower Five True Vertebrae.	ORANG.											
	Six Males.						Average for Males.	Three Females.			Average for Females.	Average for both Sexes.
I.	74.4	76.9	75.4	66.6j	79.6	74	74.5	87.1	83.3	73.3	81.2	76.7
II.	90	85.1	89.2	71.4	82.1	78.8	82.7	102.1	88.3	89.6	98.5	86.3
III.	90.4	82.1	82.7	78.6	85.1	86.7	83.4	105	84.1	83.3	90.3	85.3
IV.	92.8	83.6	102	75	85.1	85.7	86.4	102.4	84.1	77.4	87.9	87.5
V.	100	92.3	90.9	85.1	92.3	104.1	94.1	95	84.1	86.2	91.7	92.2
Sagittol- vertical lumbar index,	89.5	84	88	74.3	84.8	85.8	84.2	98.3	84.8	81.9	89	85.7

THE OCCASIONAL EIGHTH TRUE RIB IN MAN AND
ITS RELATION TO RIGHT HANDEDNESS.¹ By
D. J. CUNNINGHAM, M.D. Edin. and Dubl., *Professor of
Anatomy, Trinity College, Dublin.*

It is a matter well known to anatomists that occasionally the eighth rib is brought into direct connection with the sternum by the elongation of its cartilage. When this occurs an eighth true rib is present. Our knowledge of the conditions under which this takes place, and also of its frequency of occurrence, is by no means satisfactory. Consequently, at the beginning of last winter session I asked Mr O. L. Robinson, one of my assistant-demonstrators, to examine every subject that was brought into the dissecting-room, and to note the characters presented by the sternum and its attached costal cartilages. This was done with great care and accuracy, and the statistics which Mr Robinson handed to me at the end of the session were full of interest, and in some respects highly suggestive.

In all seventy subjects were examined, viz., forty-two females, twenty-one males, and seven in which the sex was not ascertained. With regard to the last, I may mention that the absence of record as to the sex is not due to any fault on the part of Mr Robinson, inasmuch as the specimens he had to deal with were dried lecture preparations. As it so happens, this defect in the statistics is not one of any great moment, seeing that in none of the seven specimens in question was the eighth true rib present.

In the seventy subjects thus examined Mr Robinson noted the presence of an eighth true rib fourteen times, or, in other words, in 20 per cent. It occurred seven times in females and seven times in males; but from this we must not infer that the anomaly is equally common in the two sexes, seeing that the number of females examined was twice as great as that of males.

¹ The statistics upon which this paper is based formed a part of a Report from a Committee of Investigation which was organised last winter session in the Anatomy School of Trinity College. This report was submitted to the Anatomical Section of the Royal Academy of Medicine in Ireland by Professor Cunningham, and will ultimately be published *in extenso* in the *Transactions of the Academy*.

Different forms of attachment of the eighth costal cartilage to the sternum were observed : (1) In certain cases the cartilage articulated directly with the lower end of the gladiolus ; (2) in other instances its extremity was placed in front of the ensiform cartilage, and was bound to this by ligamentous bands ; (3) in certain of those cases in which the condition was bilateral the two cartilages of opposite sides articulated with each other in front of the xiphisternum, and were bound to each other and to the sternum by ligamentous bands ; (4) in one case there was a small narrow and separate piece of cartilage which was joined by one extremity, by fibrous tissue, to the cartilage of the eighth rib, and by the other to the lower end of the sternum.

In five of the fourteen cases observed (viz., in four males and in one female anencephalous foetus) the anomaly was bilateral and symmetrical. In the remaining nine cases it was unilateral ; and in connection with these there is a point of some interest and importance, viz., that in all of them, with one exception, the anomaly appeared *on the right side*.

It is true that the above statistics are not based upon a very large number of cases, but some of the points which they indicate are so pronounced that I think we may safely discuss them with the view of testing their significance. The points to which I especially refer are—(1) the preference which the anomaly (more especially in its bilateral form) shows for the male, and (2) the very decided preference which the unilateral form shows for the right side.

Can any reasonable explanation be offered of these curious facts ? For my own part, I think that it is possible that they have something to do with right handedness. There cannot be a doubt but that the extension forwards of the eighth right costal cartilage, so that it obtains a hold upon the sternum, to some extent will strengthen the framework of the chest, and increase the stability of the basal support of the right upper limb. The greater frequency of the eighth true rib in the male may simply be due to the fact that in him a greater working power is required of the upper limbs.

It is right to add that Professor Hyrtl, of Vienna, who examined thirty subjects, found the anomaly in question only three times, and exclusively in females. From this coincidence

he was inclined to consider that the condition was due to tight lacing.¹ Many deformities, it is true, may be traced to this practice; but surely it is absurd to charge it with the production of the eighth true rib.

The presence of eight true ribs is the typical condition in the Ape. Amongst the higher Apes, however, it is not universal. It is so in the Chimpanzee, but not in the Gibbon or the Orang. In the Gibbon there is a condition intermediate between Man and the majority of the Apes. The eighth costal cartilage is long and narrow, and its pointed extremity is in contact with the ensiform cartilage without articulating with it. In the Orang the arrangement is the same as in Man.

The occasional eighth true rib in Man may therefore be regarded as a reversion to type. With the loss of his thirteenth rib Man has also lost one support to his sternum. The tendency for the reversion to occur more frequently on the right side may, as I have stated, have something to do with the greater use which he makes of his right upper limb.

Dr Lamb, of Washington (*Nature*, Nov. 1, 1888), has recently put on record twelve cases of eighth true rib in Man. All of these, with one exception, occurred in Negroes. The exceptional case occurred in an American Indian. Some observers have stated that the anomaly is more frequent in the black races, but, according to Luschka (*Anatomie der Brust*), this assertion has no foundation in fact.

It may also be interesting to note, that among the seventy subjects examined by Mr Robinson one was found in which there were only *six* true ribs on each side. This is a very unusual condition.

¹ Henle, *Handbuch der Knochenlehre*, p. 69.

FURTHER OBSERVATIONS ON THE DEVELOPMENT
OF THE TASTE-ORGANS OF MAN. By FREDERICK
TUCKERMAN, M.D., *Amherst, Massachusetts.*

IN a recent communication to the *Journal* (vol. xxii. p. 559) I gave some account of the development of the taste-organs of man. Since the appearance of my first paper I have had the opportunity, through the kindness of a friend, of investigating the tongues of human embryos of about the tenth and fourteenth week respectively.

Respecting the tongue of the embryo of the tenth week there is but little to remark. The gustatory papillæ were entirely undeveloped, nor was it possible to determine with any degree of certainty their future position. Moreover, the dorsal surface was wholly devoid of papillary elevations of any description. As there was nothing of interest, as far as gustatory structures are concerned, presented by this tongue, I shall here only consider the tongue and papillæ of the fœtus of the fourteenth week.

The upper surface of this tongue is more or less marked by papillary elevations of the mucous membrane. The elevations vary greatly in size and shape, and the spaces between them are filled for the most part by epithelium. The epithelial covering of the elevations has an average thickness of about 0.024 mm., and is composed of three rather indistinct layers. The superficial layer consists of slightly flattened cells, which, at its deeper part, become blended with those of the middle layer. The middle layer is much thicker than the preceding, and is composed of nucleated spheroidal or polyhedral cells. Below this is a deep layer consisting usually of a single row of columnar cells. The mucosa is very rich in nuclei, and, at short intervals, is penetrated quite deeply by the proliferations of the epithelium. These proliferations of the epithelium indicate the future position of the glands and their ducts. The striped muscle-fibres of the tongue are clearly shown, but their striæ are exceedingly faint.

Several papillæ of the circumvallate type, in the early stages

of development, are present. One of these papillæ was 0.090 mm. in height, and measured the same in breadth. Another measured 0.096 mm. in height and was 0.11 mm. in diameter. The trenches of the papillæ are undifferentiated, but their future position is clearly indicated. Fungiform papillæ, in various stages of growth, are scattered over the dorsum, and at the sides of the back of the tongue the lateral gustatory organs are sufficiently advanced to be perceptible.

A few bulbs were detected in the circumvallate papillæ of the fœtus, but, unfortunately, little could be learned of their structural details. The best marked bulb was spheroidal in shape, and in some respects resembled those of the soft palate and epiglottis. It measured 0.030 mm. in length and 0.027 in breadth, and was placed vertically in the long axis of the papilla, with its lower two-thirds resting in a cavity of the mucosa. The outer extremity of the bulb penetrated the superficial layers of the epithelium.

In this embryo the bulb-bearing papillæ were usually smaller, while the bulbs themselves were larger than those of the fœtus of the end of the fourth month, the tongue of which I had previously studied.

While embryonic taste-bulbs were wanting in the tongue of a ten weeks' embryo, it is not improbable that they may yet be found in the incipient stages of growth in one of the twelfth week of intrauterine life.

ABNORMAL VASCULAR SUPPLY TO THE LIVER. By
HUMPHRY D. ROLLESTON, M.B. Cantab., M.R.C.P.

IN the body of a man aged 68 years, who died from bronchitis, dissected during this long vacation (1889) in the dissecting-room of the University of Cambridge, the following anomalous arterial supply to the liver existed :—

In place of a single hepatic trunk from the coeliac axis there were three arteries—

I. A branch from the gastric artery, which divided into (*a*) a large branch which ran into the left lobe of the liver, and (*b*) another, half the calibre of the first, which sunk into the fissure for the ductus venosus; its ultimate distribution was found by dissection to be to the left lobe of the liver.

The origin of this abnormal hepatic artery is due to a further development of the inosculation between the pyloric branch of the hepatic and the gastric artery. There was, in addition, a free communication between the two vessels on the lesser curvature of the stomach; a pyloric branch being given off by the vessel next to be described.

II. An artery arising from the coeliac axis and taking the course of the normal hepatic artery to the liver. It gave off a pyloric branch, two branches to the Spigelian lobe, and then sunk into the portal fissure to terminate in the left lobe of the liver.

This vessel was at its origin about half the size of the vessel (I.) derived from the gastric artery. The artery in question was evidently the normal hepatic, much diminished in size and curtailed in its distribution.

III. The third vessel arose from the superior mesenteric, and, passing up between the head of the pancreas and duodenum, passed through the right pancreatico-gastric fold and the gastro-hepatic omentum to the portal fissure. It then split up into four branches of unequal size—(*a*) the cystic artery ran downwards to the gall bladder; (*b*) continuing the course of the vessel was a small artery which passed under the right branch of the portal vein into the caudate lobe; lying on each side of the last were (*c*, *d*) two arteries, considerably larger than the two first, which both passed into the right lobe of the liver.

From its distribution to the right lobe of the liver, and from its giving off the cystic artery, this vessel represents the right branch of the hepatic. Its origin from the superior mesenteric is due to the anastomosis between the inferior pancreatico-duodenal of that artery with the superior pancreatico-duodenal from the gastro-duodenal branch of the hepatic becoming dilated up to supply the needs of the right lobe of the liver.

The right lobe of the liver received its blood from the superior mesenteric by one trunk. The left by two vessels, (1) the normal

hepatic, altered in distribution and diminished in size, (2) from the gastric artery. The left lobe was not by any means larger than its normal relation to the right demanded.

The whole liver, though somewhat irregular in shape, was not cirrhotic or morbidly altered. Its weight was 29 oz.

The occurrence of abnormal arteries to the liver is not uncommon, the trunks arising either from the aorta, the superior mesenteric, or the gastric artery. Accessory hepatic arteries are also met with, taking origin from one of above-mentioned trunks.¹

In this case the presence of two accessory hepatic arteries, arising from the superior mesenteric and from the gastric respectively, is noteworthy.

¹ *Quain*, vol. i. p. 438.



PROCEEDINGS OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

AUGUST 1889.

THE Summer Meeting was held at 4.30 P.M. on August 15, in the Theatre of the Medical School, Leeds. In the absence of the President, the Chair was taken by Mr FREDERICK TREVES. There was a good attendance of Members and Visitors.

The Secretary read Dr AMBROSE BIRMINGHAM's paper entitled, *Notes on the Arrangement of the Lumbar and Sacral Nerves in a Subject with Six Lumbar Vertebrae*.

Professor ALEXANDER FRASER of Dublin then read the following papers, of which abstracts are given below:—

1. *Photography as an Aid in Morphological Investigation.*

The author treated first of all of the difficulties under which the anatomist, histologist, or embryologist laboured in illustrating their work properly by the methods at present in use, where they had to depend either on the skill of their own pencils, or on that of the artist hired for the occasion, or on the slight aid that the camera lucida could afford them.

He had endeavoured to overcome these difficulties by adopting the photographic method, which, for the ends he had in view, fell into two divisions:—(1) For the reproduction of the several divisions of the young or adult human body, life size; and (2) for the enlargement of serial, histological, or embryological sections for purposes of reconstruction.

As regards the first end, the author detailed the manner in which he prepared the heads of the subjects examined, avoiding all solutions that were coloured, and using only a solution of corrosive sublimate; of his method of fixing them by embedding in plaster of Paris; then of the large apparatus which he employed, that had to be worked vertically, using a large rapid rectilinear lens of long focus, so as to give proper working distance to reproduce natural size and avoid all distortion. By these means he had been able to work through the head and neck from every point of view in a serial manner, reproducing every view life size. He had also been able to show the diminu-

tion in the round of the head, when it was projected on a plane surface, by employing a system of tapes placed in a fixed manner on the head. In addition, the essentials of three views, all from nature, could be shown by proper timing on one plate, the views running in this way, the skin view being a fixed one on all the plates,—skin, bone, and brain,—skin, dura, and brain,—skin, pia, and brain,—skin, external surface of brain, and central parts of same,—and so on indefinitely, in this manner making the head and neck practically transparent.

As regards the second end, a different apparatus had to be used, viz., an enlarging lantern with a rapid rectilinear lens of short focus, the oxyhydrogen light, and Morgan and Kidd's, or the Eastman sensitive bromide paper; in addition, a special carrier had to be made, into which twelve slides of the Leipzig or eighteen of the English form could be placed at one time. Each cover-glass, on a slide, with frequently as many as one hundred sections under it, required only four seconds' exposure with the full aperture of the lens; by popping the latter, changing the sensitive paper, and pushing the carrier along the breadth of a slide, the next in the series could be enlarged. And so on to the end of the twelve or eighteen slides, when the carrier could again be refilled; in this way he had enlarged the serial sections of the entire brain of an adult rodent, and the serial sections of several embryos in an evening. The ease and celerity with which this can be done, and the beauty of the enlargements, have to be seen to be appreciated.

Full details of the two applications of this method, with illustrations, will be republished shortly.

2. *On Nerve Terminations in the Thyroid Gland.*

Prof. FRASER stated that he had found bodies resembling touch corpuscles in serial sections of the thyroid gland from half-grown Cats, that these were imbedded in considerable numbers in the lymphoid tissue situated internal to the capsule of the gland on its dorsal surface.

3. *On the Pyramidal Tracts of certain Rodents.*

Prof. FRASER stated that when he first made serial sections of the entire adult brain and cord of the Rat, Mouse, and Guinea Pig, nearly three years ago, and found that in these three animals the pyramidal tracts passed into the posterior columns of the cord where they lay adjacent to the posterior commissure, and not into the lateral columns, he thought he had fallen on something new, but on looking over the literature he found that Stieda had described it in the Mouse in Bd. xix. and xx. of Siebold and v. Kölliker's *Zeitschrift*; that Flechsig had also noted it in his work, *Die Leitungsbahnen im Gehirn und Rückenmark*, Leipzig, 1876, although he considered it to be the decussation of the inter-olivary layer and not that of the true pyramidal tracts. Spitzka also, in a very able paper on "The Comparative Anatomy of the Pyramid Tract," in the *Journal of Comparative Medicine and Surgery* for January 1886, described it for the Rat, while quite re-

cently v. Lenhossék, in No. 7 of this year's (1889) *Anatomischer Anzeiger*, has again drawn attention to the fact by describing it in young Mice and Guinea Pigs, and comparing these with the position of the tracts in young Cats and Rabbits.

Finding that it had previously been described, the author had not published his observations on these three rodents until his knowledge of these tracts, and their true relations to the posterior, lateral, and anterior columns of the cord, had become more extensive by the examination of their relations in a large number of other vertebrates.

T. WARDROP GRIFFITHS and Mr J. OLIVER read their paper on the *Cutaneous Nerves of the Trunk, with special reference to Herpes Zoster*.

R. W. REID, Lecturer on Anatomy, St Thomas's Hospital, showed the following specimens:—

1. *A Female Subject showing Cervical Ribs.*

This specimen shows the cervical vertebræ, the upper two dorsal, the first pair of ribs, part of the manubrium sterni, and on both sides a cervical rib.

The first ribs have their normal disposition, but each presents a prominent tubercle, situated just behind the groove for the subclavian artery. Articulating with this tubercle by a diarthrodial joint is the anterior end of the corresponding cervical rib. On the left side the cervical rib measures $1\frac{7}{8}$ inch, and on the right $2\frac{1}{8}$ inches. The heads of both cervical ribs articulate with the body of the seventh cervical vertebra, and by means of their tubercles they articulate with the transverse processes of same vertebra. The vertebral arteries entered the foramina of the fifth cervical vertebra. The brachial plexuses lay in front of the necks and under cover of the distal ends of the cervical ribs. The subclavian arteries occupied their normal positions on the first pair of ribs.

2. *Fifth Lumbar Vertebra, showing Persistence on both sides of a Suture in the Neural Arch between the Upper and Lower Articular Processes.*

This specimen belonged to a disarticulated skeleton which was in other ways normal. The sutures lie in such a position that the spinous process, laminae, and inferior articular processes form a segment quite distinct from the rest of the bone.

The vertebra corresponds to specimens already described by W. Turner, Neugebauer, Shattock, and Sutton.

The apparently anomalous position of these sutures is explained by the mode of formation of the neural arch in some of the lower mammals, such as the Cetacea.

From the age of the subject it is impossible to say whether a neuro-central suture was present on each side in the normal position, or

whether the pedicles, transverse and superior articular processes were formed as apophyses from the centrum.

3. *Calvaria of a Tumbler, from Sir Astley Cooper's Collection in St Thomas's Hospital Museum.*

This specimen shows marked flattening of the upper surface of the cranium in the neighbourhood of the bregma. From before backwards the flattening measures about $2\frac{1}{4}$ inches, and the cranium is slightly concave in that direction. On the interior the calvaria presents a low convexity corresponding to the flattening noticed on the upper surface.

The calvaria is unusually thin, and the sutures are very well marked. A persistent frontal suture is present.

C. B. LOCKWOOD and F. E. WITHERS described a specimen of *Right Aortic Arch* obtained from the dissecting-room. In this case the aorta passed at first upwards and to the right side—the ascending portion of the arch; the vessels then turned backwards and to the left, forming an arch with the concavity forwards, passing behind the trachea and œsophagus, which two structures lie in the concavity of this transverse portion of the arch; having reached the left side of the œsophagus, the aorta turns forward and so completes the concavity; here the vessel ends anteriorly in a diverticulum, which superiorly gives off the left subclavian artery; inferiorly it is connected with the pulmonary artery (at the junction of the right with the left) by the ductus arteriosus; and quite posteriorly it is continued downwards as the descending or thoracic aorta. The descending aorta starts from the transverse part of the arch almost at a right angle at the middle of the vertebral column.

The highest part of the arch ascends as high as the middle of the body of the third dorsal vertebra.

Branches.—The ascending part of the arch on its anterior aspect gives off the right and left common carotid arteries; the two vessels arise close together, almost by a common trunk (at any rate by a common opening in the aorta), the left being the lower and more anterior of the two.

The right subclavian is given off at the top of the ascending part of the arch.

The left subclavian is given off from the extremity of the transverse part of the arch, at the diverticulum.

The thoracic duct passes up on the left side of the aorta, under the extremity of the transverse arch, beneath the left subclavian artery; here it turns to the left, and crosses the vertebral artery, lying between it and its accompanying vein; the duct then crosses behind the internal jugular, and terminates by opening into the junction of the internal jugular and left subclavian veins.

In addition to these peculiarities, a suspensory ligament of the œsophagus was found, which passed from the left side of the œsophagus

just below the transverse portion of the arch of aorta, over the aorta and thoracic duct, upwards and backwards to the vertebral column, being attached to the anterior surfaces of the inferior margins of the body of the third and upper half of the body of the fourth dorsal vertebra, as well as to the intervening intervertebral disc.

The vagus of the right side passed downwards over the subclavian artery and over the aorta, as this vessel makes its first turn backwards, here it gave off its recurrent branch, which ascended in grooves between trachea and œsophagus. The main trunk of the nerve passed down behind the right bronchus.

T. WARDROP GRIFFITHS and M. J. OLIVER also showed a number of specimens from the Leeds School of Medicine, and Professor ALEXANDER FRASER a large collection of Photographs.

Fig. 1

a. 8.



Fig. 5.

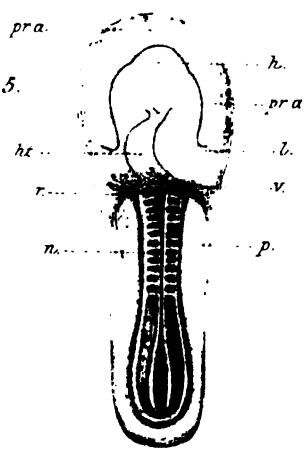


Fig. 8.

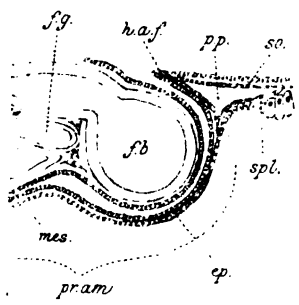
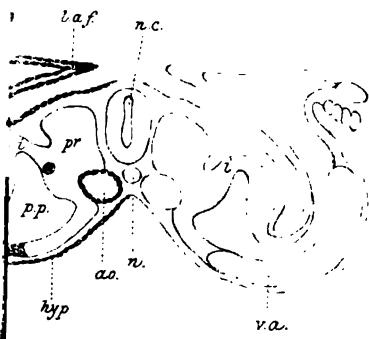
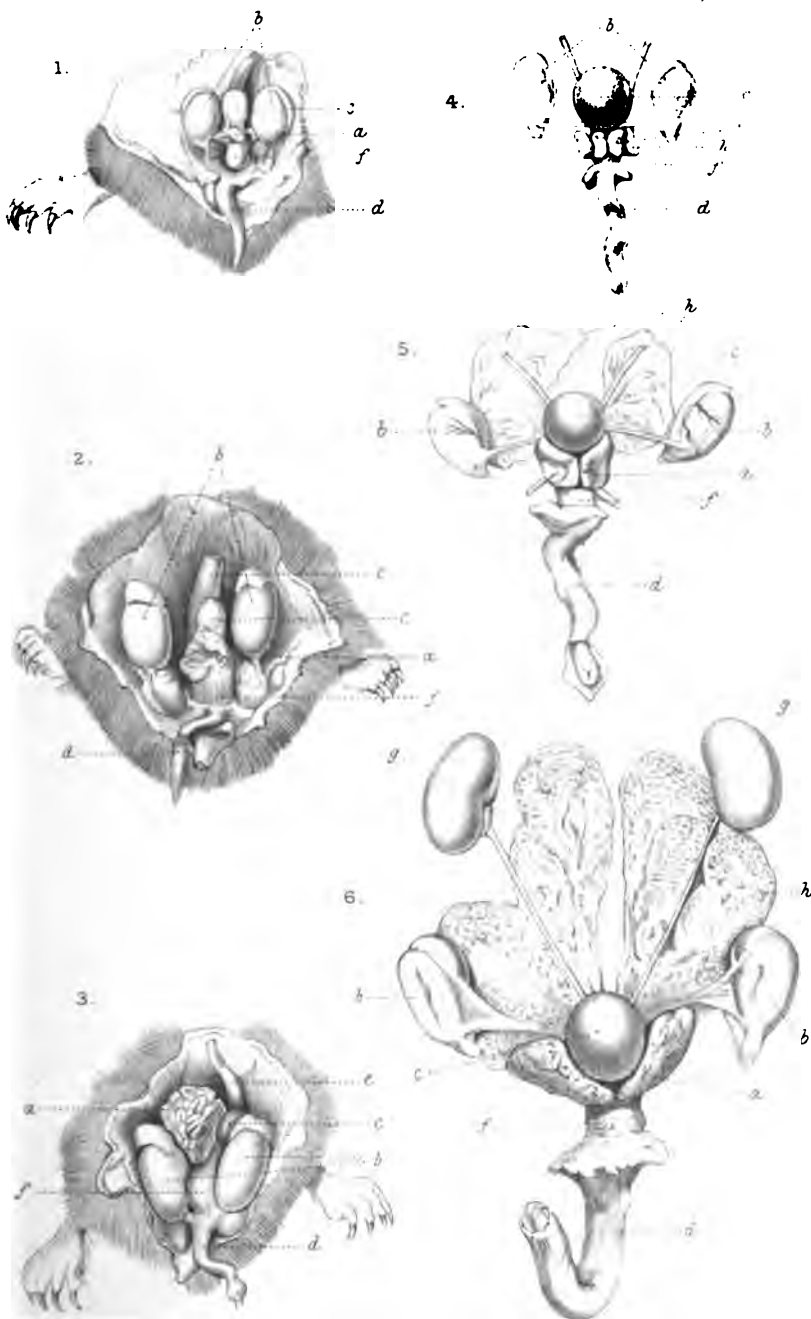


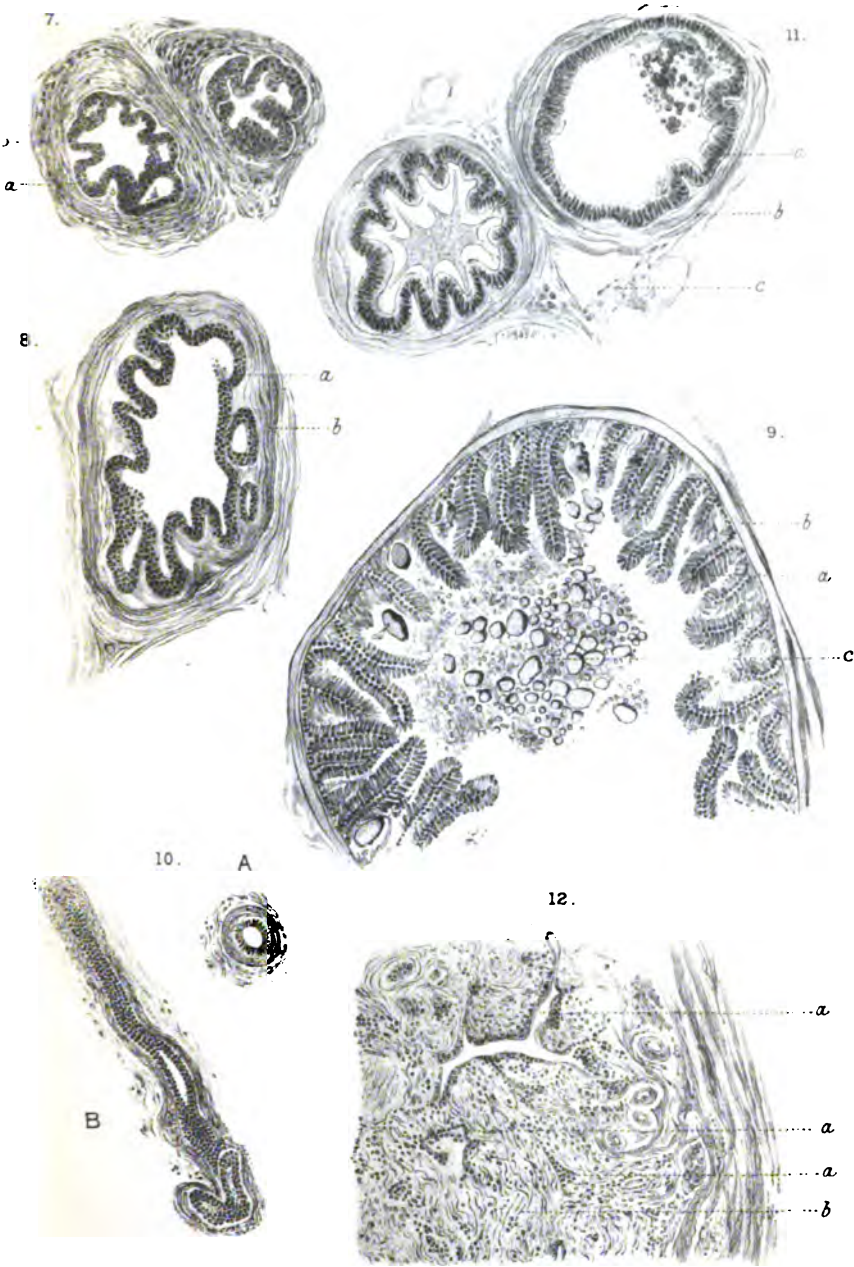
Fig. 10.





PROSTATE GLAND.

F. Huth, Lith.



F. Ruth, Lith. Edm.

PROSTATE GLAND.

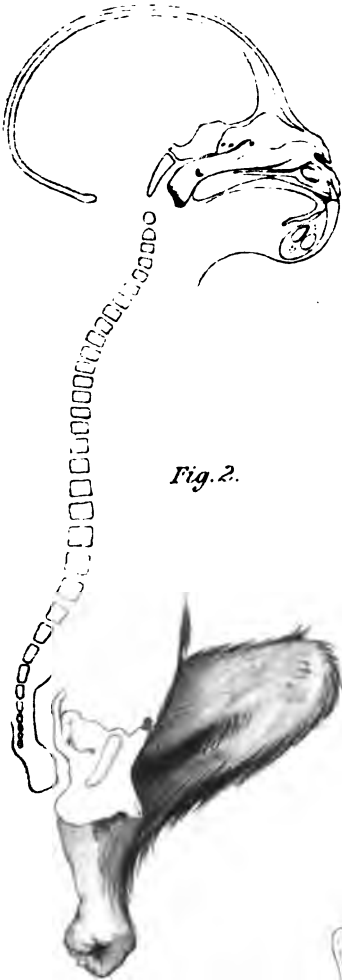


Fig. 2.

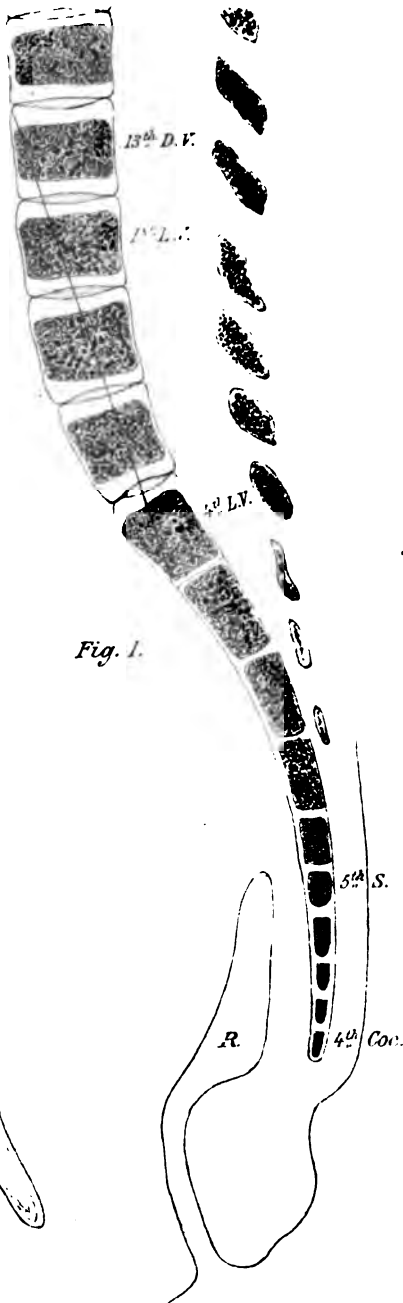


Fig. 1.

F. Ruth, Lith. Edin.

SPINE OF YOUNG GORILLA.

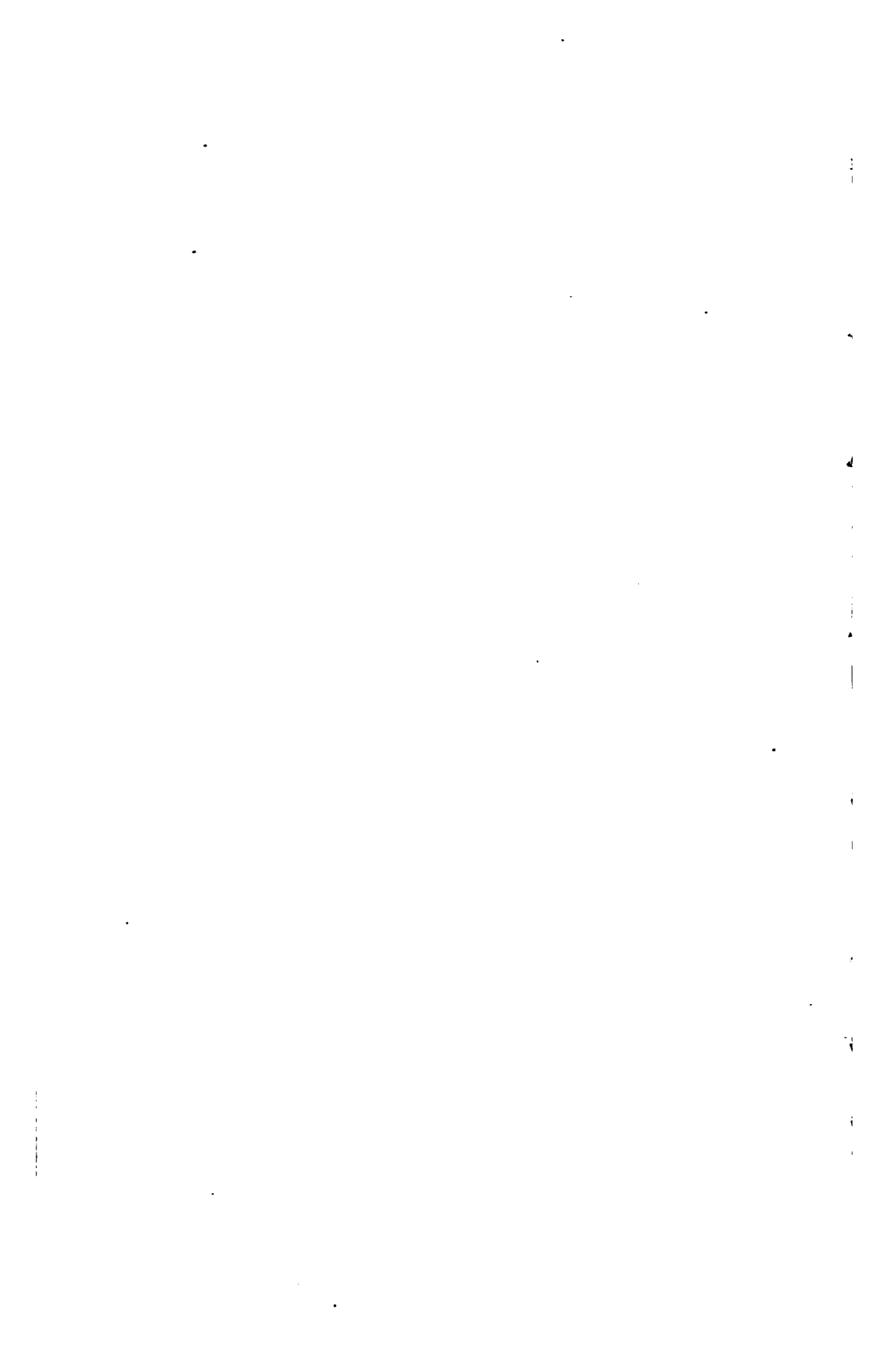


Fig. 1.

SP



Fig. 4.

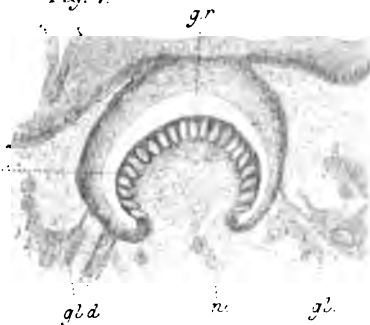


Fig. 2.



Fig. 5.



Fig. 3.

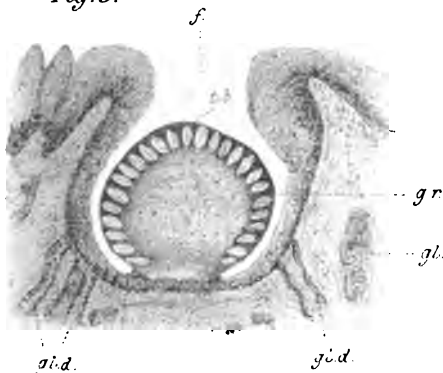


Fig. 6.

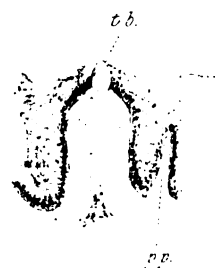


Fig. 7.



Fig. 1.



Fig. 4.



Fig. 2.



Fig. 5.



Fig. 6.



Fig. 3.

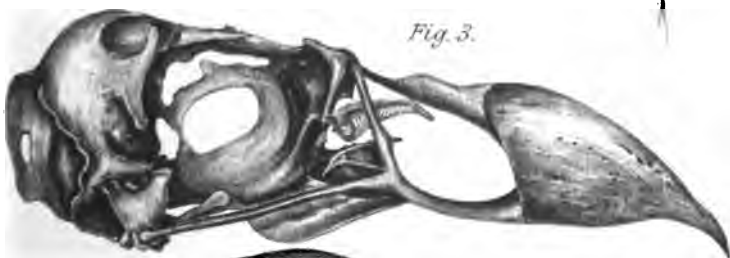




Fig. 7.



Fig. 9.



Fig. 8.



Fig. 10.



Fig. 11.



Fig. 12.



Fig. 15.



Fig. 14.



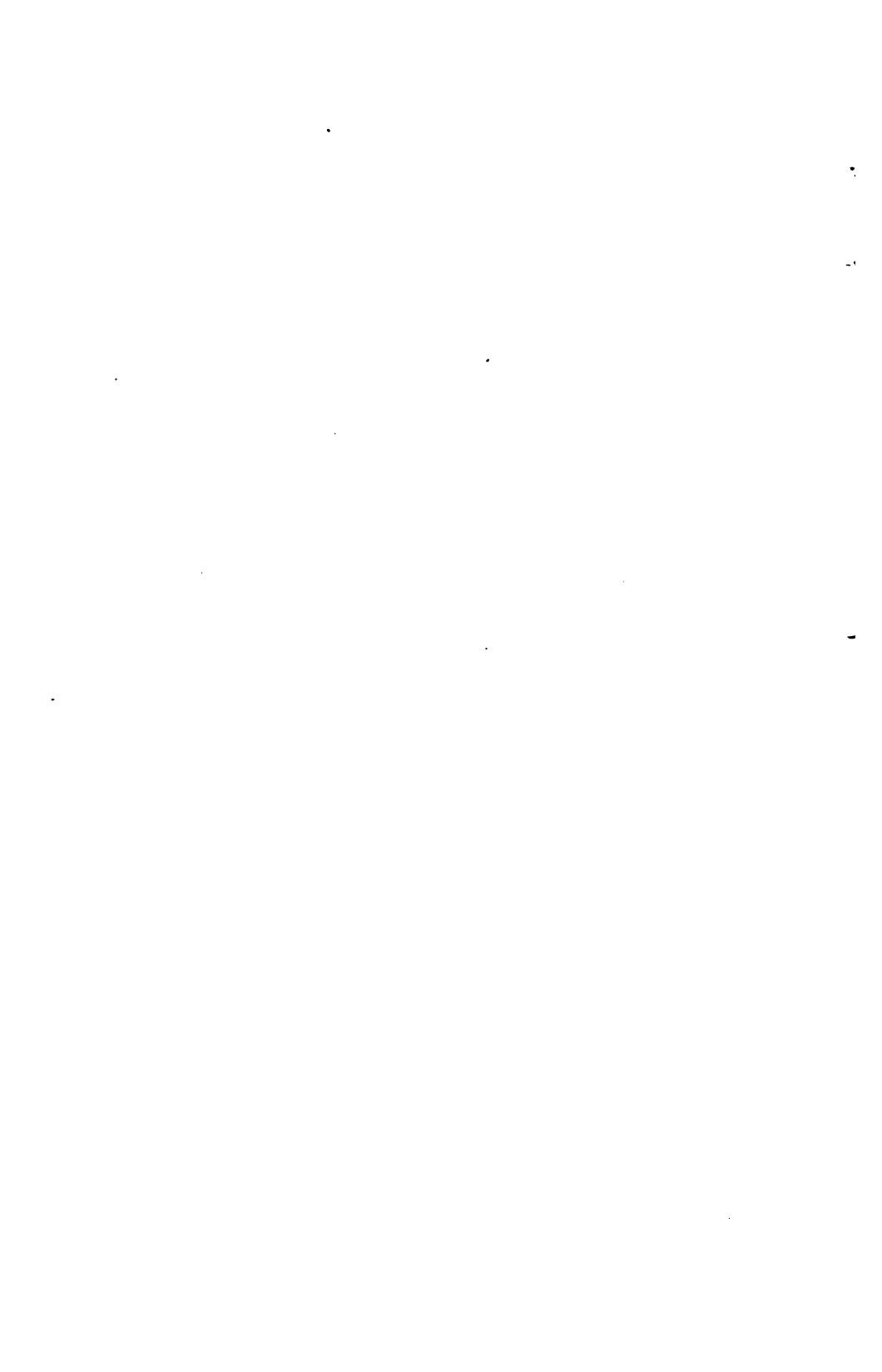
Fig. 13.



Fig. 16.



Fig. 17.



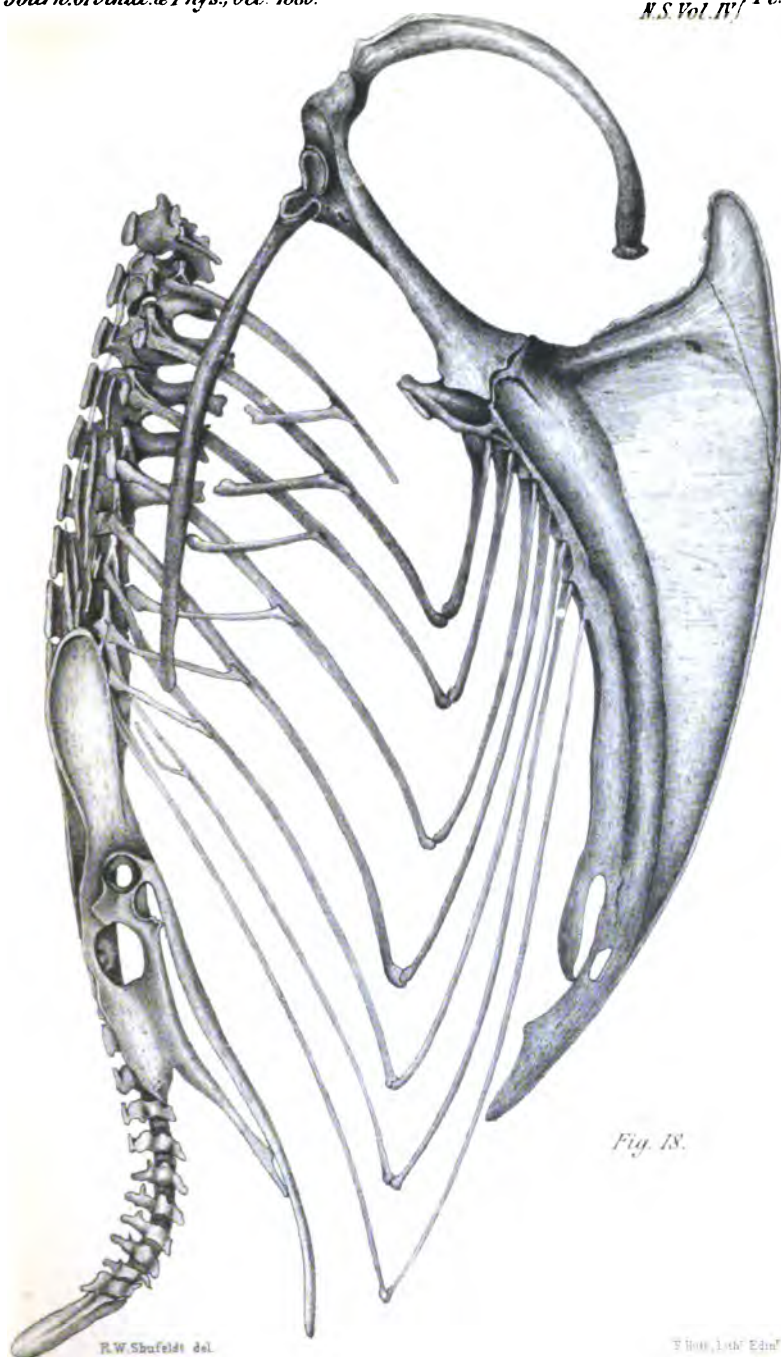


Fig. 18.

ARCTIC & SUBARCTIC WATERBIRDS.

Journal of Anatomy and Physiology.

THE INTRAPARIETAL SULCUS OF THE BRAIN. By
D. J. CUNNINGHAM, M.D., *Professor of Anatomy, Trinity
College, Dublin.* (PLATE IX.)

THE intraparietal sulcus of the brain was first described and named by Sir William Turner, in 1866, in a paper on the brain of the Chimpanzee.¹ In the month following he described it in the human brain, in a lecture² which he delivered to the Royal Medical Society in Edinburgh. Prior to this it had, however, been accurately figured not only in the brain of Man but also in the brain of the Ape. The description which Sir William Turner gave has in all its essential features been followed in most of our anatomical text-books. According to Professor Schäfer³ the sulcus

"ascends at first parallel to the furrow of Rolando and then turns backwards horizontally to the back of the lobe, extending nearly to the termination of the parieto-occipital fissure, past which it is often continued into the occipital lobe."

It therefore consists of a vertical part, which separates the supramarginal convolution from the ascending parietal convolution, and a horizontal part, which intervenes between the superior and inferior parietal lobules. But in addition to these a furrow is mentioned, under the name of the post-central sulcus, which stands in close association with the intraparietal sulcus.

¹ *Proc. Roy. Soc. Edin.*, 19th Feb. 1866.

² "The Convolutions of the Human Cerebrum topographically considered." *Edinburgh Medical Journal*, June 1866, and as a separate publication, Edinburgh, 1866.

In the same year the intraparietal sulcus was also independently described by Dr Adolf Pansch of Kiel, under the name of sulcus parietalis (*De Sulcis et Gyris in Cerebris Simiarum et Hominum*, Kiliae, 1866).

³ Quain's *Anatomy*, 9th ed., vol. ii. p. 336.

It is placed above the vertical part of the latter, and is interposed between the ascending parietal convolution and the superior parietal lobule.

Leaving out of count the relations which the intraparietal sulcus establishes in the occipital lobe, the above description is all that could be desired from a morphological point of view. It recognises the triple constitution of the parietal portion of the sulcus, and hints at occipital connections which are of the highest interest and importance. It fails, however, in so far that the arrangement of the three limbs which is detailed is not the usual one. There are several varieties of intraparietal sulcus. The one which is referred to in the above description only occurs in about 16 per cent. of cerebral hemispheres. All the different varieties of the sulcus can be explained and understood by a reference to its mode of appearance in the foetal brain, and to its condition in the brain of the Ape. In what follows we shall distinguish the three parietal limbs of the sulcus under the names of (a) *ramus verticalis inferior*, (b) *ramus verticalis superior*, and (c) *ramus horizontalis*. The occipital part we shall designate *the ramus occipitalis*.

The development of the intraparietal sulcus is attended with so much variability in different brains that it is a matter of extreme difficulty to decide upon what is in reality the typical arrangement of its several parts. The details which I give under this head are derived not only from an examination of foetal brains in my own possession, but also from a study of the masterly memoirs of Ecker¹ and Pansch,² and of the plates which accompany the writings of Reichert³ and Bischoff.⁴

The sulcus in the sixth month of intra-uterine life is in the form of two parts, viz., an anterior and a posterior. The anterior part appears in the interval between the horizontal limb of the Sylvian fissure and the fissure of Rolando. It ascends for a

¹ Ecker, "Zur Entwicklungsgeschichte der Furchen und Windungen der Grosshirn-Hemisphären im Fetus des Menschen," *Archiv für Anthropol.* dritte Band. drittes und viertes Heft, 1869.

² Pansch, "Ueber die typische Anordnung der Furchen und Windungen auf den Grosshirn-hemisphären des Menschen und der Affen," *Archiv für Anthropol.*, 1869.

³ Reichert, *Der Bau des Menschlichen Gehirns*, Leipzig, 1861.

⁴ Bischoff, "Die Grosshirn-windungen des Menschen," *Aus den abhandlung der Akad. der Wiss.*, 11 cl. x. bd., 11 Abth.

short distance and then curves backwards over the extremity of the Sylvian fissure (*vide* Reichert, pl. xii. figs. 49 and 50; also Bischoff, pl. iv. figs. 7, 8, 9). It may be regarded as representing the *ramus verticalis inferior* and the *ramus horizontalis* of the fully developed sulcus. The hinder part is the *ramus occipitalis*, and it usually appears as a distinct factor. It extends backwards on the outer face of the hemisphere a short distance from its upper margin. Commencing in front of the notch formed by the upper end of the internal perpendicular fissure it proceeds backwards beyond it into the occipital lobe (*vide* Ecker, pl. ii. figs. 1, 6, and 7; also Reichert, pl. xii. figs. 50 and 51). Reichert reckons it as one of his "peripherischen Primärfurchen." But an additional part of the same system of furrows soon makes itself evident. This is a short vertical sulcus behind the upper part of the fissure of Rolando (*ramus verticalis superior*). Reichert also includes it amongst the "peripherischen Primärfurchen." It may remain distinct and separate (Reichert, pl. xii. figs. 49, 50, and 51; also Bischoff, pl. iv. fig. 9), more frequently it extends downwards and joins the *ramus verticalis inferior* (*vide* Ecker, pl. ii. fig. 7). By this union a long furrow is formed behind the fissure of Rolando, and it is to this that Ecker gives the name of *sulcus post-centralis*.

In the admirable account which is given by Pansch of the typical arrangement of the furrows on the foetal hemisphere, the *ramus occipitalis* of the intraparietal sulcus is not enumerated as a "Primärfurche." In other respects, although expressed differently, his description accords with the foregoing. He remarks—"Also auch hier, wenn denn doch einmal ein sogenannter allgemeiner Typus aufgestellt werden soll, wird man einen 'Stamm,' einen 'obern Ast,' und einen 'hintern Ast' der dritten radiären Primärfurche annehmen dürfen." The third radial primary furrow to which he refers is the intraparietal sulcus, the stem is the *ramus verticalis inferior*, the upper branch is the *ramus verticalis superior*, and the hinder branch is the *ramus horizontalis*.

But, as I have mentioned, considerable variability is exhibited in the mode of appearance and in the relation to each other of the different parts of the intraparietal sulcus, and such

being the case, we can only appreciate the morphological importance of its different factors by an appeal to the brain of the Ape. By this means we are able to accord to each its proper value. Let us take the cerebrum of a Baboon. I select this Ape, not on account of its presenting an arrangement of the convolutions which may be regarded as being more typical than that found in many other species, but because I happen to possess fourteen cerebral hemispheres taken from the Chacma Baboon, and the occasional variations which one meets in the disposition of the furrows in the same species are often of considerable value in the determination of homological relationships.

In the Baboon, as in the vast majority of Apes, the most apparent part of the intraparietal sulcus is present in the form of a sharply-cut oblique fissure, which traverses the parietal lobe from its antero-inferior angle to its postero-superior angle (Pl. IX. fig. 5, c). This fissure represents the ramus verticalis inferior, the ramus horizontalis, and a portion of the ramus occipitalis of the human sulcus. The ramus verticalis superior is in many Apes entirely unrepresented; but in the Baboon, and, indeed, in a large number of other forms, there is a more or less distinct indication of it present (fig. 5, e). It may take the form of a stellate depression behind the upper part of the fissure of Rolando, or it may be present in the shape of a shallow linear furrow. Both conditions are met with in the Baboon, and in three of the fourteen cerebral hemispheres which I have before me this furrow extends downwards, and effects a junction with the main part of the fissure, thereby indicating a subdivision of the latter into two portions corresponding to the lower vertical and horizontal parts of the human sulcus. This appears to be the usual condition in the Chimpanzee (fig. 2) and the Gibbon. I found it present in three specimens of the former and in one of the latter. Bischoff also figures it in the Gibbon,¹ and several authors in the Chimpanzee. In the Orang, however, the ramus verticalis superior remains separate, whilst in the Gorilla it may present either condition.²

¹ *Beiträge zur Anatomie des Hylobates leuciscus*, pl. ii. fig. 1; aus *Abhandlung der K. bayer. Akad. der. W.*, Cl. xi. Bd. x. Abth. iii., 1870.

² Broca, *Mémoires sur le Cerveau de l'homme publiés par le Docteur S. Pozzi*, p. 636.

The *ramus occipitalis* of the intraparietal sulcus as it is seen in the Ape presents some features of extreme interest; but it is better to defer these until we deal with the corresponding segment of the fissure in the human brain.

Putting aside then for the present the *ramus occipitalis*, it is clear, both from the study of the foetal brain and the brain of the Ape, that of the remaining three parts of the intraparietal sulcus, two, viz., the *ramus horizontalis* and *ramus verticalis inferior*, are originally continuous and identical, whereas the third, the *ramus verticalis superior*, may be looked upon as having an independent origin. I have recently examined sixty-two human cerebral hemispheres with the view of ascertaining the more usual disposition of the intraparietal sulcus. Amongst these I met with every possible form of combination of the three segments of the sulcus. No less than five varieties may be recognised.

Variety I. All the three parts of the sulcus separate.—It is very uncommon to meet with a cerebral hemisphere in which all the three segments of the intraparietal sulcus are separated from each other by superficial and distinct bridging convolutions.

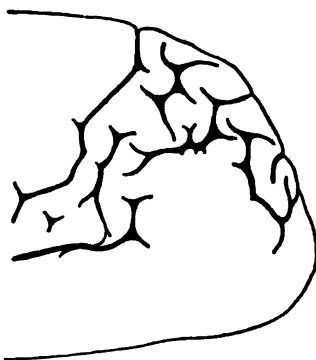


FIG. 6.—Posterior Part of the Left Hemisphere of a young Man 25 years old. The four factors of the intraparietal sulcus are all separate and distinct.

Of the sixty-two hemispheres examined, only four exhibited this condition. These comprised (a) both hemispheres of a newly-born full-time male child; (b) the right hemisphere of a boy of 5 years old; (c) the left hemisphere of a young man 25 years old.

Variety II. Ramus horizontalis confluent with the ramus verticalis inferior; ramus verticalis superior separate.—This is the condition of the intraparietal sulcus which was originally described by Sir William Turner, and in the last edition of Quain's *Anatomy* it is given as the normal arrangement. The development of the fissure and its condition in the Ape would both alike appear to indicate this variety as the typical

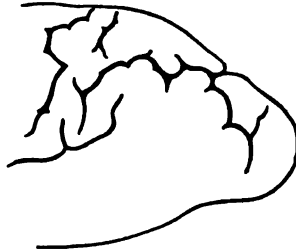


FIG. 7.—Left Hemisphere of a new-born Male Child. It shows the typical condition of the intraparietal sulcus.

one, but certainly it is not the most common. It was only discovered in ten out of the sixty-two hemispheres examined, or, in other words, in 16 per cent. The hemispheres in which it occurred were derived from the following sources:—(a) Two from a newly-born full-time male child; (b) one from a girl *æt.* 4 years; (c) one from a boy *æt.* 5 years; (d) one from a youth *æt.* 15 years; (e) two from two adult male negroes; (f) three from three adult Irish males.

In three of these the *ramus horizontalis* was partially separated from the *ramus verticalis inferior* by a deeply-placed annectant gyrus which passed from the superior parietal lobule to the supramarginal convolution. Sir William Turner speaks of the angle of junction of the ascending and horizontal parts of the sulcus as a frequent seat for a bridging gyrus in the human brain. It indicates a tendency for the horizontal limb to become divorced from the lower vertical limb, and affords the explanation as to the manner in which Variety I. of the sulcus is produced. The presence of this bridging gyrus is peculiarly a human characteristic.¹ So far as I am

¹ As we shall see later on, the occipital ramus of the intraparietal sulcus is, in the great majority of cases, also separated from the main portion of the sulcus by

aware, it has not been noticed in any Ape brain, and I have failed to discover it in the specimens of the brains of the Chimpanzee and Orang which I possess.

Variety III. Vertical limbs confluent; horizontal limb separate.—In Plate IX. fig. 1, a well-marked example of this variety of the fissure is represented. At first sight the hemisphere appears to be traversed by two fissures of Rolando and three central convolutions. The hinder of the two transverse sulci is the result of the complete union of the two vertical limbs of the intraparietal sulcus. It is the *sulcus post-centralis* of Ecker or the *sulcus post-rolandicus* of Pansch divorced from the ramus horizontalis. A thick superficial bridging convolution which connects the superior parietal lobule and the supramarginal convolution cuts off the ramus horizontalis completely. No evidence as to its double nature can be gained by examining the bottom of this long transverse furrow. It is uniformly deep throughout, and possesses a depth not far short of that of the fissure of Rolando. Its walls interlock through the presence of numerous secondary gyri, but there is no trace of a bridging convolution.¹

It is not common, however, to find a specimen of this variety of the intraparietal sulcus so characteristic as that figured in Plate IX. I possess only one other hemisphere, obtained from an adult male, in which all the essential features are the same. Nevertheless, of the sixty-two hemispheres examined, ten came within the same class. In all of these there was a long continuous furrow placed behind the ascending parietal convolution, and parallel with the fissure of Rolando. As a rule, the upper part of this sulcus was shallower than the lower part, and in three cases it was partially cut off from it by a deeply-placed bridging gyrus, which crossed the bottom of the furrow and connected the posterior parietal lobule with the ascending parietal convolution. Further, the superficial bridge which intervened

a superficial or deep bridging convolution. These links between the upper and lower parietal lobules are regarded by Wernicke as typical in the human brain (*Arch. f. Psychiatrie*, Bd. vi. S. 323). In the Baboon a concealed gyrus sometimes marks off the occipital part of the sulcus.

¹ A condition of the intraparietal sulcus similar to this was described by Luy, "Description d'une circonvolution supplémentaire signalée dans certains cerveaux humaine," *Gaz. d. Méd.*, Paris, 1876, xlix. p. 588.

between the horizontal ramus of the fissure and the vertical part was not so strongly marked. In the memoir by Ecker upon the development of the furrows and convolutions of the human brain, this condition of the intraparietal sulcus is represented in the process of formation in the right hemisphere of a seven months' foetus (plate ii. fig. 6); and in the atlas accompanying Gratiolet's *Mémoire sur les plis cérébraux de l'homme* the same variety is exhibited in a very complete form in the left hemisphere of the well-known "Hottentot Venus."

The ten hemispheres which I have described as belonging to this variety were taken from the following subjects:—(a) One from a girl, æt. 4 years; (b) two from two adult negro males; (c) six from Irish adult males; (d) one from an Irish adult female.

Variety IV. The three parts of the sulcus confluent.—This is by far the most usual condition of the intraparietal sulcus in the human brain. It was present in thirty-five of the cerebral hemispheres examined, or, in other words, in about 56

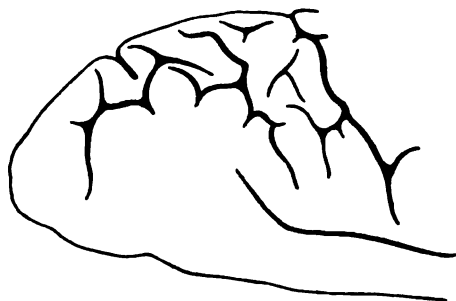


FIG. 8.—Posterior Part of the Left Hemisphere of an elderly Female. The more usual condition of the intraparietal sulcus is exhibited.

per cent. The examples to which I refer were obtained as follows:—(a) Four from female children, aged respectively 6 months, 1 year, and 11 years; (b) two from two boys, aged 12 and 15 years; (c) fourteen from adult females (including two negresses); (d) eight from adult Irish males; (e) seven from Irish adults, whose sex could not be ascertained.

In several of these indications were present which pointed to a tendency on the part of the sulcus to approximate the conditions exhibited in Varieties II. and III. Thus, in six a deep concealed bridging gyrus passed between the superior parietal

lobule and the supra-marginal convolution, and partially cut off the horizontal limb of the sulcus. Féré¹ has stated that in 75 per cent. this annectant gyrus is present. Certainly this is not my experience.

On the Continent it is usual to describe this variety of the intraparietal sulcus as the normal arrangement;² and in the numerous memoirs in which the cerebral hemispheres have been drawn from nature, it will generally be observed to be the condition depicted. It is further interesting to note that the Chimpanzee (fig. 2), Gibbon, and in some cases the Baboon and other Apes, exhibit a similar disposition of the three rami of the intraparietal sulcus.

In Man, therefore, we may say that the general tendency exhibited is towards a union of the two originally distinct vertical limbs, and a divorce from those of the horizontal limb, which in its origin and history is clearly continuous with the lower vertical limb.

Variety V. Ramus horizontalis joined to the lower end of the ramus verticalis superior, lower vertical limb separate.—This is a very rare form of the intraparietal sulcus. It was noted in only two of the sixty-two hemispheres examined, viz., in the right hemisphere of a negress and in the left hemisphere of an adult subject obtained in the dissecting-room, and of which the sex was not ascertained. It is difficult to account for this variety. In several cases belonging to Class IV. I observed the long sulcus, formed by the union of the two vertical rami, crossed by two deep and concealed gyri. The upper of these was placed at what might be supposed to be the junction between the two vertical limbs, whereas the second bridged across the ramus verticalis inferior. If we were to suppose the latter to come to the surface and the former to remain undeveloped, the condition exhibited by this variety would be produced.

Of the sixty-two cerebral hemispheres examined, we have been able to refer sixty-one to one or other of the five varieties indicated. In the hemisphere which could not be so disposed

¹ I have not been able to obtain the article by Féré in which this statement is made. The quotation is taken from Schwalbe's *Neurologie*, p. 552.

² For example, see Schwalbe's work on *Neurologie*, p. 551, and Gegenbaur's *Text-book of Anatomy*, p. 842, vol. ii., 3rd edition.

of there was an almost total absence of the ramus verticalis superior of the intraparietal sulcus. Immediately above the junction of the ramus horizontalis, with the vertical stem, the latter ran across the ascending parietal convolution, and joined the fissure of Rolando. This condition was brought about by a bending down of a portion of the ascending parietal convolution, in the form of a deep concealed gyrus. And whilst referring to this case, I may mention that a junction between the ramus verticalis superior and the fissure of Rolando is occasionally met with. As a rule, however, the whole of the limb involved is not absorbed, as in the instance referred to.

At a recent meeting of the Anatomical Society, Professor Lockwood exhibited the cast of a brain which presented an extremely interesting anomaly. His description runs thus:—

“The right fissure of Rolando was as follows:—It began above by opening into the great longitudinal fissure, and after descending downwards and forwards above an inch, bifurcated to enclose a long narrow convolution. The two limbs which embraced this convolution ended by opening separately into the posterior limb of the fissure of Sylvius.” . . .

Mr Lockwood was inclined to believe that the “anomalous convolution” belonged to the parietal lobe.¹ I have not had the advantage of examining this interesting cast, but I believe that the condition is produced by the ramus verticalis inferior of the intraparietal sulcus running across the ascending parietal convolution and joining the fissure of Rolando. The figure which accompanies the description seems to indicate this. The “anomalous convolution,” therefore, would represent the lower two-thirds of the ascending parietal convolution.

I would not venture to offer this explanation had I not observed somewhat similar cases in my study of the different varieties of intraparietal sulcus. Both of the vertical limbs may establish connections with the fissure of Rolando. The upper limb may run bodily into the Rolandic fissure, whilst the lower limb may be connected with it by a secondary branch. In all I have seen four cases of this kind, but it is not necessary to describe these separately or in detail. In three the upper vertical limb of the intraparietal sulcus alone was involved. It

¹ *Jour. Anat. and Phys.*, vol. xxiii. part iii. ; *Proc. Anat. Soc.*, p. 17.

joined the fissure of Rolando at a varying distance from the upper free margin of the hemisphere. In one case, already referred to, it was almost entirely absorbed in this way. In the fourth case there was a double connection. Not only did the upper vertical limb run into the fissure of Rolando about an inch distant from the upper margin of the hemisphere, but also the lower vertical limb was joined to it by a cross-branch. In every instance the junction was effected by a knuckling down of the ascending parietal convolution, and this could easily be seen by opening up the lips of the junctional sulcus. When

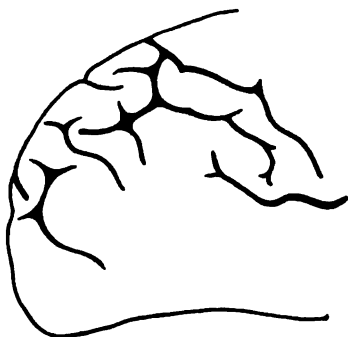


FIG. 9.—Posterior Part of Right Hemisphere of a Female 35 years old. It shows the ramus verticalis superior crossing the ascending parietal convolution and joining the fissure of Rolando.

such a connection occurs, it appears to be common for the ascending frontal convolution to be divided in one or more places as well. This occurred in three of my cases. In these the upper part of the precentral sulcus effected a communication with the fissure of Rolando, and in Mr Lockwood's figure a similar condition appears to exist.¹

We know the influence which the shape of the cranial envelope has upon the direction of the sulci of the brain. A restraint placed upon the growth-energy of the cerebral surface

¹ Since the above was written, Mr Lockwood has had the kindness to send me the cast of the brain in question. The arrangement of the sulci is more complicated than I had anticipated; but I still believe that the explanation which I have given above holds good. The three parietal parts of the intraparietal sulcus are all separate, and the ramus verticalis inferior cuts the ascending parietal convolution in two, and thus effects a junction with the fissure of Rolando. It affords an example then of the rare Variety I.

of there was an almost total absence of the ramus verticalis superior of the intraparietal sulcus. Immediately above the junction of the ramus horizontalis, with the vertical stem, the latter ran across the ascending parietal convolution, and joined the fissure of Rolando. This condition was brought about by a bending down of a portion of the ascending parietal convolution, in the form of a deep concealed gyrus. And whilst referring to this case, I may mention that a junction between the ramus verticalis superior and the fissure of Rolando is occasionally met with. As a rule, however, the whole of the limb involved is not absorbed, as in the instance referred to.

At a recent meeting of the Anatomical Society, Professor Lockwood exhibited the cast of a brain which presented an extremely interesting anomaly. His description runs thus:—

“The right fissure of Rolando was as follows:—It began above by opening into the great longitudinal fissure, and after descending downwards and forwards above an inch, bifurcated to enclose a long narrow convolution. The two limbs which embraced this convolution ended by opening separately into the posterior limb of the fissure of Sylvius.” . . .

Mr Lockwood was inclined to believe that the “anomalous convolution” belonged to the parietal lobe.¹ I have not had the advantage of examining this interesting cast, but I believe that the condition is produced by the ramus verticalis inferior of the intraparietal sulcus running across the ascending parietal convolution and joining the fissure of Rolando. The figure which accompanies the description seems to indicate this. The “anomalous convolution,” therefore, would represent the lower two-thirds of the ascending parietal convolution.

I would not venture to offer this explanation had I not observed somewhat similar cases in my study of the different varieties of intraparietal sulcus. Both of the vertical limbs may establish connections with the fissure of Rolando. The upper limb may run bodily into the Rolandic fissure, whilst the lower limb may be connected with it by a secondary branch. In all I have seen four cases of this kind, but it is not necessary to describe these separately or in detail. In three the upper vertical limb of the intraparietal sulcus alone was involved. It

¹ *Jour. Anat. and Phys.*, vol. xxiii. part iii. ; *Proc. Anat. Soc.*, p. 17.

joined the fissure of Rolando at a varying distance from the upper free margin of the hemisphere. In one case, already referred to, it was almost entirely absorbed in this way. In the fourth case there was a double connection. Not only did the upper vertical limb run into the fissure of Rolando about an inch distant from the upper margin of the hemisphere, but also the lower vertical limb was joined to it by a cross-branch. In every instance the junction was effected by a knuckling down of the ascending parietal convolution, and this could easily be seen by opening up the lips of the junctional sulcus. When



FIG. 9.—Posterior Part of Right Hemisphere of a Female 35 years old. It shows the ramus verticalis superior crossing the ascending parietal convolution and joining the fissure of Rolando.

such a connection occurs, it appears to be common for the ascending frontal convolution to be divided in one or more places as well. This occurred in three of my cases. In these the upper part of the precentral sulcus effected a communication with the fissure of Rolando, and in Mr Lockwood's figure a similar condition appears to exist.¹

We know the influence which the shape of the cranial envelope has upon the direction of the sulci of the brain. A restraint placed upon the growth-energy of the cerebral surface

¹ Since the above was written, Mr Lockwood has had the kindness to send me the cast of the brain in question. The arrangement of the sulci is more complicated than I had anticipated; but I still believe that the explanation which I have given above holds good. The three parietal parts of the intraparietal sulcus are all separate, and the ramus verticalis inferior cuts the ascending parietal convolution in two, and thus effects a junction with the fissure of Rolando. It affords an example then of the rare Variety I.

in a longitudinal direction tends to produce sulci and convolutions, which pursue a course at right angles to the direction of the restraint. On the other hand, a restriction placed upon the surface-growth in the vertical direction predisposes to the formation of oblique or longitudinal sulci.¹ A dipping down of one or other of the central convolutions, as in the cases referred to, may naturally then be ascribed to the latter cause.²

Ramus Occipitalis of the Intraparietal Sulcus.—This is undoubtedly the most interesting part of the intraparietal sulcus, and in the human brain its exact homology, with the condition present in the Ape brain, is somewhat difficult to ascertain. A careful description of its course and relationships is given by Schwalbe,³ Ecker,⁴ Gegenbaur,⁵ Pansch,⁶ and other authors. Schwalbe states that after overstepping the artificial boundary line of the occipital lobe, the ramus occipitalis may end by joining the sulcus occipitalis transversus of Ecker, or be continued to the occipital pole as the superior occipital sulcus. The transverse occipital sulcus is a short furrow which runs transversely across a small extent of the outer surface of the occipital lobe a short distance behind the external parieto-occipital fissure. It is very generally regarded as the representative of the so-called external parieto-occipital fissure in the Ape, and therefore as a distinct and independent fissural integer. This conception of the sulcus transversus we believe requires

¹ "Ueber den Einfluss der Schädelform auf die Richtung der Grosshirnwindungen," Von Ludwig Meyer, *Centralblatt für die Med. Wiss.*, 1876, Oct. 1, No. 43; also article by Meynert, "Medizinische Jahrbücher von der K. K. Gesellschaft der Ärzte," Jahrgang 1876.

² I am aware that this contention would be disputed by Richter, who puts so much faith in the "pulsatorische Erschütterungen" of the hemispheres for the production of the secondary furrows ("Ueber die Entstehung der Grosshirnwindungen, *Archiv für path. Anatomie*, Virchow, 1887, p. 398). The late Professor Pansch would also in all probability have taken exception to it. In his article entitled, "Bemerkungen über die Faltungen des Grosshirns, &c. (*Archiv f. Psychiatrie*, Band viii. Heft 2), he remarks, "Den Meynert'schen Anschauungen über die Abhängigkeit der Windungsrichtung von der Form des Schädels vermag ich vorläufig nicht beizustimmen."

³ *Lehrbuch der Neurologie*.

⁴ "Entwicklungsgeschichte der Furchen und Windungen," &c., &c., already referred to; and also his book upon "The Human Brain."

⁵ *Lehrbuch der Anatomie des Menschen*, Band 11.

⁶ *Die Furchen und Wülste*, Berlin, 1879.

some slight modification. Further, the account given by Schwalbe is apt to produce the impression that the *ramus occipitalis* is always continuous with the main portion of the intraparietal sulcus, whereas, as we shall see later on, this is very far from being the case.

In no less than thirty-six of the sixty-two hemispheres which I have examined the *ramus occipitalis* was quite distinct and separate from the horizontal limb of the intraparietal fissure. Further, in eleven of the twenty-six cases in which it was confluent with the intraparietal sulcus a deep bridging convolution was found partially interrupting the course of the furrow at the point of junction. In those cases where the *ramus occipitalis* was separate, it began, as a rule, in the superior parietal lobule above the extremity of the *ramus horizontalis* of the intraparietal sulcus.

A point worth noting is the fact that of sixteen cerebral hemispheres obtained from children, twelve presented the *ramus occipitalis* in a separate form. With regard to adult brains an equal proportion of both sexes was found in each class, and the same may be said for the negro brains which were examined.

Upon phylogenetic grounds I have been led to believe that the sulcus *occipitalis transversus* of Ecker cannot be regarded as entirely corresponding with the so-called external parieto-occipitalis fissure in the Ape; nor can it be regarded as constituting an entirely independent fissural element. It belongs in part, if not in whole, to the same fissural system as the intraparietal sulcus. In support of this contention, it will be necessary to bring forward some facts in connection with the condition in which the sulcus is found in certain of the Apes.

Let us, in the first instance, examine the simple arrangement which is present in the brain of *Cebus capucinus* (fig. 4). The intraparietal sulcus ascends obliquely in an upward and backward direction, and approaches the upper margin of the hemisphere where the internal perpendicular fissure makes its appearance on the outer surface. Here it bends upon itself and turns sharply downwards for a short distance under cover of the operculum.¹ The internal perpendicular fissure opens freely

¹ I possess three cerebral hemispheres taken from the *Cebus*. In one of these the short descending limb ends before it reaches the anterior lip of the operculum.

into the angle of bending. Three parts then are here recognizable, viz., a long ascending limb, a short descending limb, and the internal perpendicular fissure as it appears on the outer surface, and all three are directly and uninterruptedly continuous. The descending limb represents a part, but not the whole, of the ramus occipitalis of the intraparietal sulcus in Man.

The arrangement which we find in the *Cebus* may be regarded "as the ground-plan in most of the Apes" (Pansch). But before we go further it is very essential that we should come to some understanding as to what is meant by the term "external parieto-occipital sulcus" as applied to the brain of the Ape. Does it refer to the sulcus which is seen on the outer surface of the cerebrum, in a line with the upper end of the internal perpendicular fissure and along the anterior lip of the operculum, or does it refer to the bottom of the pocket enclosed by the operculum? If we give to the term the former signification, then we may state that such a sulcus does not exist in the human brain, for the simple reason that in it there is no operculum. If, on the other hand, we confine its meaning to the bottom of the slit and regard the operculum as a structure formed by the forward growth of the posterior lip of an original transverse furrow, it remains for us to see what relationship is presented to this by the sulcus transversus of the human brain.

Pansch has very aptly compared the occipital operculum of the Ape to the fronto-parietal operculum which covers the island of Reil. In this case we may compare the bottom of the opercular recess in the occipital lobe to the furrow which bounds the island of Reil above, and the superficial furrow along the anterior edge of the occipital operculum with the fissure of Sylvius. We know that the island of Reil is produced by a stoppage of outward growth over the area which it is ultimately to occupy. In the first instance there is no furrow in relation to its upper border; this only appears with the downward growth of the fronto-parietal operculum. The question which arises, therefore, is whether, seeing we have no occipital operculum in the human brain, it is likely that we should have a furrow corresponding to the "affenspalte." I merely mention this as a difficulty in the

way of our regarding the sulcus transversus as homologous with the bottom of the "affenspalte."¹ Knowing so little, however, as we do concerning the mode of development of the occipital operculum, no great stress can be placed upon this argument.

In carrying out our comparison between the intraparietal sulcus in Man and the corresponding sulcus in the Ape, it is necessary to remove or throw back the operculum.

We have already examined the intraparietal fissure in the Cebus, and seen it end in the form of a short descending branch under cover of the operculum. This is quite distinct from the bottom of the opercular recess, which is carried backwards for a short distance behind it.

The Baboon will serve for our next stage (fig. 5). In the brain of this form there is a deeply placed annectant gyrus (the first bridging convolution) which partially cuts off the internal perpendicular fissure from the intraparietal sulcus (*h*). This gyrus is sharply defined in front by a branch of the intraparietal sulcus which extends upwards in front of it (*f*). Posteriorly it is limited by a furrow which corresponds with the upper part of the bottom of the opercular slit (*i*), whilst externally it is limited by the short descending limb of the intraparietal fissure. The latter, however, has no connection with the bottom of the recess formed by the operculum.

The condition of the fissure in the Chimpanzee (fig. 2) leads us directly up to Man. The first annectant gyrus is still partially hidden from view, but it has risen much nearer to the surface (*h*). It constitutes a distinct barrier to the communication between the internal perpendicular fissure as it turns outwards on the hemisphere and the intraparietal fissure. On removal of the operculum the descending short limb of the intraparietal sulcus is seen to bound the first annectant gyrus externally, and then bifurcate. The upper limb runs directly upwards, and joining the bottom of the "affenspalte," limits the first annectant gyrus posteriorly (*k*), whilst the lower limb turns downwards under cover of the operculum, but is soon called to a halt, because the deep and hidden second annectant gyrus interposes itself in the

¹ The term "affenspalte" is used in Germany to indicate the recess or slit under the operculum of the occipital lobe.

way. The upper terminal branch is a new branch. We have seen in the Baboon how a branch is sent up from the intraparietal sulcus in front of the first annectant gyrus; here in the Chimpanzee there is a branch which is sent up behind it, but this loses itself in the bottom of the "affenspalte." The lower terminal branch of the bifurcation is simply the down-turned end of the intraparietal sulcus as we have seen it in the Cebus and the Baboon.

If we now suppose the operculum abolished, and the two annectant gyri in relation to the intraparietal sulcus raised to the surface, we have the condition present in Man. The terminal bifurcation of the intraparietal sulcus, with its widely spread out limbs, constitutes the sulcus transversus. Instead of being completely or partially concealed, as in the lower forms, it is now exposed to view on the surface.

As we have noted, the occipital part of the intraparietal sulcus is either continuous with the main part of the fissure, or else it has a separate origin in the superior parietal lobule. As it passes backwards it sends a branch in front of the first annectant gyrus, and in its typical condition divides in the occipital lobe beyond the gyrus into two terminal branches. These are so widely spread out that they deviate from each other very nearly in the same straight line, and constitute the sulcus transversus. The lower limb of the bifurcation owes its origin undoubtedly to the intraparietal sulcus; it is the lower part of the short descending limb in the Ape which is only brought into view when the operculum is removed. The upper limb bounds the first annectant gyrus posteriorly, and it is more difficult to decide upon its nature. In the Baboon the first annectant gyrus is bounded behind by the upper part of the "affenspalte" alone, whilst in the Chimpanzee a branch is given off from the intraparietal, which turns up and joins this part of the "affenspalte," giving rise to the appearance of a terminal bifurcation of the intraparietal sulcus. It would appear, therefore, that if the sulcus transversus has any relation to the "affenspalte" it is only in its upper part.

I make these statements in full knowledge of the condition of the intraparietal sulcus in such forms as the white-crowned Mangaby (*Cercocebus æthiops*, Pl. IX. fig. 3). In the brain of

this Ape, and indeed in many others, the intraparietal sulcus sends up the usual branch in front of the first annectant gyrus. It then runs round its outer aspect, and, approaching the bottom of the recess under the operculum, bifurcates into two branches, which, in diverging from each other, lose their identity in the bottom of the "affenspalte."

If we now refer the condition present in Man to the ground-plan as exhibited in the Ape, it will be apparent that the *ramus occipitalis* of the human brain corresponds with the upper part of the ascending limb of the intraparietal sulcus, together with a small portion of the descending limb. The lower part of the latter forms the inferior portion of the sulcus transversus.

The position which the sulcus transversus occupies is very variable. In nine brains, measured *in situ*, I found its average distance behind the upper end of the internal perpendicular fissure to be 15 mm., although in one case it was twice that distance. As a general rule it lies in front of the parieto-occipital suture. In one case it coincided with the suture. Its position is influenced by the massiveness of the first annectant gyrus.

In brains taken from brachycephalic skulls, a long transverse fissure may sometimes be seen traversing very nearly the entire extent of the outer surface of the hemisphere, and occupying a position which corresponds with the artificial anterior boundary of the occipital lobe. This is not the sulcus transversus. It crosses the *ramus occipitalis*, and breaks it up into two parts, which are separated from it by vertical annectant gyri. I have two brains in my possession which exhibit this condition, and in both the hinder bifurcation of the *ramus occipitalis* (sulcus transversus) is seen behind the fissure in question.

I have tried to show that the phylogenetic evolution of the sulcus transversus would seem to indicate that it is not altogether an independent sulcus, but belongs partly to the same system as the intraparietal. The ontogenetic development of the sulcus does not furnish evidence of a satisfactory nature. Ecker figures the brain of an eighth month fœtus in which the sulcus transversus is divorced from the occipital part of the intraparietal fissure, although in the same plate he depicts

another brain of the same age in which the two sulci are continuous. Again, in plate xvi. of the *Atlas* by Leuret and Gratiolet, a figure is given of the brain of a seven months' foetus, in which the sulcus transversus is shown in direct connection with the ramus occipitalis of the intraparietal sulcus.

Pansch refuses to admit that the sulcus transversus is a primary sulcus.

Bischoff, it is true, describes and figures a sulcus under the name of the fissura perpendicularis externa. He includes it in the group of "Primärfurchen," and states that it appears in the seventh month, but vanishes in the eighth month of foetal life. It belongs to that class of formations therefore, he remarks, which only, in certain forms, attain their complete development, whilst in others they are arrested or completely disappear. This statement by Bischoff has never received confirmation. Ecker points out that most probably the fissure referred to is one which appears in the fifth month, and vanishes in the seventh month of intra-uterine life. Certainly it has nothing to do with the sulcus transversus. It is one which I have studied closely in a large series of foetal brains, and the relationships of which I purpose discussing in a memoir at present in course of preparation.¹ Although somewhat outside the scope of the present paper, I may briefly state some facts regarding it. On the outer face of the occipital lobe of the young embryo two fissures may make their appearance. These correspond in every respect with the internal perpendicular and calcarine fissures on the inner face of the hemisphere. The vertical infolding (Bischoff's fissura perpendicularis externa), according to my observations, very rarely occur. I have no specimens in my possession in which it is seen, but in a foetal brain, preserved in the Oxford Museum, it is present in a well-marked form.² It is well figured by Bischoff, and has only a transitory existence, although it is just possible that it may be the precursor of the transverse furrow which I have referred to as sometimes crossing the brain

¹ Cunningham Memoir No. VI., *Royal Irish Academy*, "A Contribution to the Anatomy of the Cerebral Hemispheres."

² It is through the kindness of Professor Victor Horsley that I have been able to make this observation. In fact, I may say that he saved me from falling into a serious error in connection with this question by furnishing me with a series of beautiful photographs of the specimens in the Oxford Museum.

on a line with the internal perpendicular fissure. Bischoff is altogether wrong as to the time which he gives for its appearance and disappearance. With regard to the second fissure which appears on the outer face of the occipital lobe of the foetus, the following facts may be noticed:—(1) It produces a distinct infolding of the hemisphere wall. (2) It is placed, not vertically, but very obliquely near the lower margin of the occipital part of the hemisphere. (3) It corresponds on the outer surface of the hemisphere to the calcarine fissure on the inner face, and the bulgings which they both form into the primitive ventricular cavity lie exactly opposite each other. (4) It apparently disappears in the human brain, but it is retained in the Ape. (5) As the hinder end of the hemisphere becomes solid, and the ventricular cavity no longer reaches the extremity, it is only the anterior part of the calcarine fissure which forms the calcar avis; the fissure in question is shorter than the calcarine fissure, and in many Apes its anterior end just falls short of the posterior horn of the ventricle; but in some it just reaches it, and in these cases it forms a bulging on the outer side of the ventricle corresponding to the calcar avis on the inner side.

I had not intended to discuss the homologies which undoubtedly exist between the fissures and convolutions of the carnivorous brain and those of the brain of the primates; but there are some aspects of the question which it is impossible for me to shirk. It is now very generally admitted that the anterior part of the uppermost arching furrow in the brain of the carnivora (the *sulcus coronalis*) has its homologue in the fissure of Rolando. Such being the case, the anterior limb of the second arching furrow (*sulcus suprasylvius*) is the representative of the intraparietal sulcus in the brain of Man and the Apes. So far everything is clear and satisfactory; but can we offer any explanation as to the homologies of the "affenspalte," and the downwardly directed posterior part of the intraparietal sulcus in the Ape (Pl. IX. figs. 4 and 5). In the brain of the Cebus these sulci are quite distinct from each other, and in some cases the intraparietal sulcus ends altogether in front of the occipital operculum. In the present instance I can only deal very briefly with this question; but I may be

allowed to state my belief that the descending limb of the intraparietal sulcus, so well exhibited in the brain of the Cebus and other Apes, is to be regarded as a part of the posterior limb of the middle arching fissure (*sulcus suprasylvius*) of the carnivorous brain divorced from its temporo-sphenoidal continuation (*parallel sulcus*). It is possible, therefore, that the "Affenspalte" may have its homologue in a portion of the posterior limb of the uppermost "Bogenfurche" of the carnivorous brain.

Sir William Turner, in his masterly article upon the cerebral convolutions of the Seals and Walrus,¹ has cleared away from our path one great difficulty in arriving at a true conception of the convolutions in the brain of the Carnivora, by offering a most ingenious and highly probable explanation of the origin of the Island of Reil in Man and the Apes, and of the disappearance coincident with this of the Sylvian convolution (lowest arching convolution) of the carnivorous brain.

I regret that I have not had the advantage of studying Rüdinger's article upon the "affenspalte"² and the intraparietal sulcus. All my attempts to secure this paper have, up to the present, proved unavailing; but from a short reference to it in the memoir by Professor Max Flesch, upon the parieto-occipital fissure,³ I am led to suppose that the results Rüdinger has arrived at are not antagonistic to those that I have advanced in the foregoing article.

EXPLANATION OF PLATE IX.

Fig. 1. Right hemisphere of an adult male (drawn on the stone from a photograph). It exhibits, in a well-marked form, the condition described in the paper as Variety III. of the intraparietal sulcus. A, Island of Reil; B, horizontal limb of the fissure of Sylvius; C, ascending limb of fissure of Sylvius; F, fissure of Rolando; G, external parieto-occipital fissure. *b* and *c*, second and third frontal convolutions; *d*, ascending frontal convolution; *e* and *h*, ascending

¹ *Jour. Anat. and Phys.*, vol. xxii.; also *Zool. Chall. Exp.*, part lxvii., 1888.

² *Ein Beitrag zur Anatomie der "Affenspalte" und der Interparietalspalte beim Menschen*, Bonn, 1887 ("Aus der Henle gewidmeten Jubiläumsschrift").

³ Albert von Kölliker's *Festschrift*, p. 379, 1887.

parietal convolution ; *f*, supramarginal convolution ; *g*, angular gyrus ; *i*, *l*, and *m*, occipital convolutions ; *n*, *o*, *p*, temporo-sphenoidal convolutions ; 1, 2, 3, and 4, annectant gyri.

Fig. 2. Posterior portion of the right hemisphere of a young female Chimpanzee. *a*, fissure of Sylvius ; *b*, fissure of Rolando ; *c*, parallel sulcus ; *d*, ramus verticalis inferior of the intraparietal sulcus ; *e*, ramus verticalis superior of the intraparietal sulcus ; *f*, ramus horizontalis of the intraparietal sulcus ; *g*, the branch which limits the first annectant gyrus in front ; *h*, the first annectant gyrus ; *i*, the internal perpendicular fissure as it turns out on the upper surface of the hemisphere (external parieto-occipital) ; *k*, the branch of the intraparietal sulcus which turns up behind the first annectant gyrus to join the "Affenspalte," *l*, second annectant gyrus ; *m*, cut surface of the occipital operculum.

Fig. 3. The posterior part of the left hemisphere of the white crowned Mangaby. *a*, parallel sulcus ; *b*, fissure of Sylvius ; *c*, intraparietal sulcus ; *d*, ramus verticalis superior ; *e*, descending limb of the intraparietal sulcus ; *f*, upper end of internal perpendicular fissure turning outwards on the upper surface of the hemisphere (external parieto-occipital) ; *g*, cut surface of occipital operculum.

Fig. 4. Posterior portion of the right cerebral hemisphere of the *Cebus capucinus*, viewed from above. *a*, Sylvian and parallel fissures combined ; *b*, fissure of Rolando ; *c*, intraparietal sulcus ; *d*, internal perpendicular fissure ; *e*, "Affenspalte," *f*, cut surface of occipital operculum.

Fig. 5. Posterior part of the right cerebral hemisphere of the Chacma Baboon looked at from above. *a*, Sylvian fissure ; *b*, parallel sulcus ; *c*, ramus verticalis inferior of the intraparietal sulcus ; *d*, fissure of Rolando ; *e*, ramus verticalis superior ; *f*, branch from intraparietal sulcus in front of the first annectant gyrus ; *g*, the upper end of the internal perpendicular fissure ; *h*, first annectant gyrus ; *i*, "Affenspalte," *k*, cut surface of the occipital operculum.

THE GUSTATORY ORGANS OF *PROCYON LOTOR*.

By FREDERICK TUCKERMAN, M.D., Amherst, Massachusetts.

(PLATE X.)

General Appearance of the Tongue.—The tongue of *Procyon lotor* is 94 mm. in length, 25 mm. in width, and 15 mm. in thickness, and is free for 20 mm. from the frænum. The extreme anterior portion is relatively thin, and terminates in an obtuse apex, the latter showing a slight tendency to become bifurcate. The under surface is smooth, and marked for a short distance by a median raphé running forwards from the frænum linguæ. The raphé soon takes the form of a rather deep groove, which is continued to the apex. The papillate surface is soft and velvety to the touch, and bears the impress of the palatal furrows. It is somewhat convex posteriorly, and more or less flattened anteriorly, and presents a nearly uniform breadth throughout. The anterior dorsal surface is impressed by a faint trace of a mesial raphé, perceptible for about 25 mm. from the tip backwards. The lateral borders, particularly in the fore part of the organ, are marked by a fringe of delicate cone-shaped papillæ, the points of which are directed upwards, backwards, and inwards. The gustatory and extreme basal regions of the tongue have the usual coarse, fleshy, recurved papillæ projecting from the surface. Fungiform papillæ of the normal type are numerous, and quite uniform in their distribution, those of the mid-dorsal region being the most conspicuous. The circumvallate papillæ, seven to ten in number, are placed in two rows, converging posteriorly, one on each side of the median line. They vary considerably in size, are more or less verrucose, and are frequently overtopped by an exuberantly developed fimbriated outer wall. There is a lateral gustatory organ at each side of the base of the tongue. The organs are in their usual position, but differ in their structural characters, I think, from any hitherto described. Each is marked externally by three small irregular openings, running transversely to

the long diameter of the tongue, the anterior one of the three being the most conspicuous.

The Circumvallate Papillæ.—These papillæ are verrucose or papillose on top, and their epithelial covering is somewhat imbricated in arrangement, and occasionally partly cornified. The sides of the papillæ are fairly vertical, and the trench surrounding each papilla is deep, and quite uniform in breadth. Serous glands are not abundant directly beneath the papillæ, but lie for the most part in the stroma at their sides. The ducts, in consequence of this arrangement of the glands, seldom open at the bottom of the trench, but pierce its outer limiting wall obliquely, the orifice of a duct being sometimes on a level with the opening of the trench.

The taste-bulbs are disposed around the lower lateral area of the papilla in a zone of sixteen closely placed tiers. From horizontal sections through the bulb-bearing portion of the papilla I estimated the mean number of bulbs in a tier at 100. If we allow for sixteen tiers, we shall have 1600 bulbs for each papilla. The bulbs are unequal in size, and exhibit much variation in shape. Owing to the difficulty of tracing the lateral contours of individual bulbs, it is not easy to state the exact dimensions of the typical taste-bulb of *Procyon lotor*. The mean variation in length appears to be from 0.051 to 0.060 mm., the mean breadth being 0.023 mm. A few bulbs attain a transverse diameter of 0.033 mm. In many bulbs the base is more or less elongated, whilst the peripheral end is slightly rounded, and without any visible neck.

I succeeded in obtaining some fairly good transverse sections of bulbs. In one of these, in which the bulb appeared to have been divided near the middle, I counted thirty cells, eighteen of which were grouped around the axis of the bulb, and were doubtless sensory in function.

The Lateral Gustatory Organs.—The openings of the lateral organs of taste, or *gustatory recesses*, occupy the site of the papillæ foliatæ, and doubtless represent those structures in this animal. They are readily distinguishable without the aid of a lens, and consist of three small irregular recesses or cavities in the mucous membrane, placed more or less perpendicularly to the surface, upon which they open by furrow- or slit-like

apertures. The anterior recess is by far the largest. The two posterior recesses are more or less rudimentary or undeveloped, and are generally devoid of bulbs. Figs. 1 and 2 represent vertical sections through different parts of the same recess. This recess has a depth of 1.35 mm., its greatest transverse diameter being about 1 mm. In fig. 3, two recesses, the anterior and middle, are shown. At the bottom of the recesses are usually (but not invariably) one or more ridges. The walls are quite thick, and lined with stratified pavement epithelium, similar in character to that covering the lingual surface. Serous glands are scattered through the sub-mucosa, and their ducts open into the recesses either between the bases of the ridges or at the sides at different levels.

The taste-bulbs of this region are distributed more or less irregularly over the circumference of the ridges. They also occur at the sides, and are collected into groups at the deeper part of the recesses. The largest number of bulbs visible in a single vertical section of a recess was 75. In a horizontal section I counted 120. The bulbs exhibit a marked difference in size, but average about 0.045 mm. in length and 0.021 mm. in breadth. Non-medullated nerve-fibres are abundant within the ridges, and appear to run to all parts of them.

The fungiform papillæ usually have one or more taste-bulbs embedded in the epithelium of their upper surface. The bulbs appear to traverse nearly the entire thickness of the epithelium, their apices in some cases reaching to its outermost layers. The bases of the bulbs, as a general rule, either touch the mucosa or rest in a shallow depression of it. More rarely a bulb will be entirely epithelial in position.

At the lower part of the anterior surface of the epiglottis are a number of bulb-like bodies. They measure 0.024 mm. in length and 0.021 mm. in breadth, and are entirely epithelial in position. In my specimens these structures were wanting on the posterior surface of the epiglottis (their usual place of occurrence), although in *Sciurus hudsonius* I have found them on both surfaces. In the sub-mucous portion of the epiglottis are embedded small mucous glands. Their ducts, which are more or less convoluted and wavy, pass through the mucous membrane and open on the anterior surface.

EXPLANATION OF PLATE X.

Fig. 1. Vertical section through the anterior recess of a lateral gustatory organ. At the bottom of the recess are three ridges. All of the ridges bear bulbs. *o.a.r.*, opening of the anterior recess; *r.*, ridges at the bottom of the recess; *t.b.*, the taste-bulbs; *gl.*, serous gland; *gl.*, serous gland, with its duct opening into a furrow formed by the ridge. $\times 30$.

Fig. 2. Vertical section through the same recess. At this point the opening of the recess is much narrower, and the opposed walls approach each other quite closely. The floor of the recess is invaginated upwards into a symmetrically curved ridge, which bears bulbs over the whole of its circumference. Into the space at each side of the base of the ridge the serous ducts open. *o.a.r.*, opening of the anterior recess; *r.*, ridge; *t.b.*, taste-bulb; *gl.d.*, the ducts of the serous glands. $\times 30$.

Fig. 3. Vertical section through the anterior and middle recesses of a lateral gustatory organ. The lower part of the anterior recess is nearly filled by a large bulb-bearing ridge. A serous gland partly occupies the basal portion of the ridge. The ducts of the serous glands open into the recess at different levels. *o.a.r.*, opening of the anterior recess; *o.m.r.*, opening of the middle recess; *r.*, ridge; *t.b.*, taste-bulbs; *gl.*, serous gland; *gl.d.*, ducts of the serous glands. $\times 30$.

Fig. 4. Horizontal section through the anterior recess of a lateral gustatory organ at about the widest part, showing the irregular shape of the cavity and the distribution of the taste-bulbs. Many ducts of the serous glands open into the recess at this level. *t.b.*, taste-bulbs; *gl.*, serous glands; *gl.d.*, ducts of the serous glands. $\times 50$.

In Dr Tuckerman's paper on the gustatory organs of *Belideus ariel*, in the October number, the figure 4 drawn by him was not reproduced, owing to want of room on the Plate; the descriptions on p. 88 of the text of figures 5-8 apply to figures 4-7 of the plate.

DRY COVER-GLASS MICROSCOPICAL PREPARATIONS. By WILLIAM STIRLING, M.D., *Professor of Physiology and Histology in The Owens College, Manchester.*

(From the Physiological Laboratory of The Owens College, Manchester.)

By the researches of bacteriologists (especially Koch) on the one hand, and Ehrlich and his pupils on the other, we have been made acquainted with the advantages of "dry cover-glass preparations." In testing for the presence of bacteria in certain tissues or fluids—*e.g.*, sputum—it is usual to press a small piece of the tissue or a little of the sputum between two cover-glasses so as to spread it out as a thin film. On separating the two cover-glasses by gliding the one off the other, a thin film is left upon both cover-glasses. These films are allowed to dry, and can be stained afterwards by means of suitable dyes. This method was applied with great success by Ehrlich¹ and his pupils in order to study the "granules" or "granulations" of various kinds that occur in the colourless corpuscles of human and other blood.

I wish to draw attention to the advantages which this method affords for the study of many tissues, not only as a means of investigation of new phenomena, but also for securing suitable demonstrations of many objects for the student of histology.

Blood-Corpuscles.—Vincent Harris² has directed attention to this method as applied to the study of blood-corpuscles. The blood was spread in thin layers upon cover-glasses, and allowed to dry in direct sunlight. The dried blood was then covered with a solution of some aniline dye, and after a time the preparation was washed in water, dried in the flame of a spirit-lamp, and allowed to cool. A second dye was then used in the same way, and the preparation was mounted in balsam

¹ *Archiv f. Anat. u. Phys., Phys. Abh.*, 1879, p. 571; *Zeits. f. klin. Med.*, Bd. i. p. 553; *Charité Annalen*, 1884, p. 107; Eugen Westphal, *Ueber Mastzellen*, Inaug. Diss., Berlin, 1880; Nordmann, *Beiträge z. Färbung d. Mastzellen*, Inaug. Diss., Berlin, 1884.

² *Quart. Jour. Micr. Sci.*, xxiii. p. 792.

without being previously passed through alcohol and clove-oil, or other clarifying agent.

Harris also fixes the dried film of blood by means of a solution of chromic acid, $\frac{1}{2}$ per cent., or bichromate of potash, 0.5 per cent. It is then acted on by alcohol, washed in water, dried, and treated with a solution of Spiller's purple.

I have repeated this experiment, and find that most beautiful preparations of blood are thereby obtained by using various combinations of aniline dyes for double-staining. In Frog's blood-corpuscles, by using eosin and iodine green, the nucleus becomes green and the hæmoglobin a coppery tint. Harris has used many combinations of aniline dyes.

Following the directions of Ehrlich, it is easy for the student of histology to repeat Ehrlich's experiments, and convince himself of the existence of different kinds of "granules" in the eucocytes.

In the method of Ehrlich, in order to fix the blood-corpuscles on the cover-glass, the cover-glasses with the film of blood are subjected for several hours to a temperature of 120° C., and the temperature must be kept fairly constant. Instead of this drying process, the cover-glasses may be passed three or four or more times through the flame of a spirit-lamp or the flame of a Bunsen burner, as recommended by Koch for preparations of bacteria. The heating process is necessary for liquids that contain a large amount of albumin, so that this substance is changed from a soluble into an insoluble condition.

The following method by Nikiforow¹ may be substituted, viz., to rapidly coagulate the proteids by placing the cover-glasses in a fluid. The covers are dried by exposure to the air, and are afterwards placed for one or two hours in a mixture composed of absolute alcohol—which must be quite free from water—and ether, equal parts. The cover-glasses are then dried by exposure to the air, and are subsequently stained by the method of Ehrlich.

The most varied combinations of aniline dyes can be used in staining the blood-corpuscles of the Frog or Newt or those of Man.

A very striking effect is obtained with a dry film of human

¹ *Zeitsch. fr. Wiss. Mikrosk.*, v. p. 340.

blood treated in this way, and afterwards stained in a saturated watery solution of methylene blue. The cover-glass is floated in the methylene blue, film-surface next the fluid, and after several hours it is washed in water and alcohol, and either allowed to dry, and is then mounted in xylol-balsam; or, after it has been dehydrated in alcohol, it is clarified in xylol and mounted in xylol-balsam. The use of clove-oil is to be avoided, as it tends to destroy the colour of the aniline dyes.

In this preparation the coloured blood-corpuscles are yellowish and unstained, while the leucocytes catch the eye at once by their pronounced blue colour. Some of them are fairly uniformly stained blue, while in others certain "granules" are stained blue. The student also sees at a glance the relative proportion of the colourless corpuscles.

By this means the long and tedious process of drying is avoided, so that the student can readily prepare for himself a great variety of combination of dyes for blood-corpuscles.

Besides staining the blood-corpuscles with one dye after another, a very good plan is to use Biondi's fluid, or rather Ehrlich's fluid as modified by Biondi.¹ Ehrlich's fluid consists of acid fuchsin and methyl blue or methyl green. The Ehrlich-Biondi fluid used is the same as that used by Heidenhain for the study of the structure of the villi of the small intestine. It consists of completely saturated watery solutions of the following:—100 c.c. orange, 20 c.c. acid fuchsin, and 50 c.c. methyl green. When required the solution is diluted in the proportion of 1 to 40 of water or thereby.

Leucocytes from Lymph-Glands.—Scrape the cut surface of a freshly-excised lymph-gland, and compress the scrapings between two cover-glasses, and stain them with methylene blue or Biondi-Ehrlich fluid.

The method, however, is equally applicable to other tissues besides blood. I find it specially well adapted for the study of epithelium.

Epithelium.—Take, for example, ciliated epithelium and goblet cells. The cells are first dissociated in Ranvier's alcohol, i.e., dilute alcohol (1:2), for twenty-four hours, and, for convenience, take the mucous membrane on the hard palate of the Frog.

¹ Pflüger's *Archiv*, Supp., Bd. xliii., 1888.

A thin film of the dissociated epithelium is pressed between two cover-glasses, and, after being dyed, they are immersed in the alcohol-ether mixture and then stained. A very good stain is methylene blue. The preparations are mounted in xylol-balsam. The cells retain their form; the nucleus is of a deeper blue than the rest of the cell, and, while the clear disc at the base of the cilia is particularly well-defined—sharper, in fact, than it is in a preparation mounted in glycerine or Farrant's solution.

The goblet cells are particularly beautiful. The contents of each cell are but slightly stained, while the nucleus is deep blue, and the small quantity of protoplasm surrounding it is of a lighter blue tint. Often the mucus projecting from the open mouths of the cells can be seen.

If a double stain be desired, steep the stained cover-glass, after staining with methylene blue, in absolute alcohol, clarify it with oil of cloves in which a little eosin is dissolved, displace the clove-oil by means of xylol, and mount in xylol-balsam. The nuclei and nucleoli now are blue, the rest of the cell of a light coppery or eosin tint.

Safranin also makes a good stain. The cells retain their shape wonderfully, and the preparations made in this way are certainly very beautiful.

Epithelium dissociated by dilute alcohol from any other epithelial surface may be used. Thus, the columnar and goblet cells of the Frog's stomach and of the intestine of the Frog or Newt, or the transitional epithelium of the bladder, make remarkably instructive and beautiful preparations. Stratified squamous epithelium from the œsophagus, *e.g.*, dissociated in a very dilute solution of potassic bichromate ($\frac{1}{8}$ — $\frac{1}{10}$ per cent.), for several days, when similarly treated, yields excellent preparations, which, after being heated, may be stained with methylene blue, methylene violet, or any other suitable dye. The same kind of preparation is readily made with the epithelium scraped from the dorsum of the tongue or inner surface of the cheek.

Bone Marrow.—Red bone marrow is so complex in its structure, and its constituents are so varied in their characters, that it is not easy to determine the relation of the one form of corpuscle to the other. The red marrow is readily obtained

from the ribs of a Guinea-Pig or Rat, and if it be examined fresh in normal saline solution, one can see distinctly the various forms of leucocytes, imperfectly formed blood-corpuscles, large cells with a twisted and convoluted nucleus, and the myeloplaxes or giant cells.

Place the red marrow in a small test-tube containing some normal saline fluid just tinged with methyl green. Shake up the fluid to diffuse and break up the red marrow. Allow the marrow to settle to the bottom of the test-tube, and spread a film of it between two cover-glasses. Stain and examine it. It may be stained in methylene blue or Biondi's fluid, and mounted in balsam. All the different kinds of cells can then be studied with great ease.

Nerve Cells.—Perhaps of all the tissues to which this method can be applied, there is none in which it yields such brilliant results as in connection with the multipolar nerve cells of the spinal cord. This method I first saw practised by Professor L. v. Thanhoffer in 1886, when I was in Buda-Pesth, and his remarkably able and beautifully illustrated monograph, published in Hungarian, has unfortunately not been translated into German. The results obtained by L. v. Thanhoffer by this method are given in a *résumé* published in German.¹

The spinal cord should be taken from a freshly-killed animal, preferably a horse, but the spinal cord of a dog, an ox, or sheep does admirably. The larger the animal the better, for as a general rule the multipolar cells are larger in the larger animals. With a sharp-pointed pair of scissors pick out a small piece of the grey matter of the anterior cornu, and squeeze it between two cover-glasses. Separate them as already directed, and after they are dry stain them in methylene blue, either a watery or an alcoholic solution. I have chiefly used the former, and mounted them in balsam. The method is so simple and satisfactory that it can be used with success by the junior student of histology. It rarely fails, and one obtains a picture of the multipolar cells which it is difficult to describe. The processes, branched and unbranched, of the cells can be traced, many of them quite across the field of the microscope; the nucleus and

¹ "Beiträge z. fein. Structur d. centr. Nervensystems," *Centralblatt f. Physiologie*, 1888.

nucleolus are sharply defined, while the body of the cell cannot be described either as homogeneous or granular, it is distinctly fibrillated, and the fibrils can be seen sweeping through the cell-substance in several different directions, and many of them can be traced either into the branched processes or axis-cylinder process of the nerve cells. I know of no method which yields such beautiful and satisfactory results, and is at the same time so simple in its execution as this one.

Thanhoffer makes another form of preparation which is in some respects equally instructive, viz., to heat the thin film of nervous matter in the flame of a Bunsen burner until the film becomes brown. The nerve cells are "fixed," and are slightly "browned." They retain their shape and other characters, and present a strikingly beautiful picture in the field of the microscope. After cooling they are mounted in balsam.

It may be objected that many of the aniline colours are fugitive, and as a matter of fact many of them are. I have had in my possession for nearly three years nerve cells stained with methylene blue, and they seem as good as ever.

I have, however, found a simple method whereby these cells can be stained by means of carmine and mounted on cover-glass preparations. Macerate for one to four or five days small parts of the grey matter of the spinal cord of a freshly-killed animal in the following mixture, proposed by Landois, for the dissociation of the elements of the nervous system:—Make saturated solutions of neutral ammonium chromate, potassic phosphate, and sodic sulphate, and take of each 5 c.c., mix and add 100 c.c. water. After three or four days transfer the pieces of tissue to a fresh quantity of the mixture, and to it add an equal volume of picro-lithium carmine. After several days the nerve cells will be found deeply stained. Crush a small piece of the stained grey matter between two cover-glasses. Mount in balsam. These preparations show distinctly the shape and other characters of the cells and their processes, but the protoplasm does not exhibit the striated appearance of the methylene blue specimens.

Blood-Vessels.—In the preparations—both the methylene blue and the heated ones—of the spinal cord, the student will find beautiful specimens of the smaller blood-vessels, especially small

arteries breaking up into capillaries. These methods give more satisfactory results, and with less trouble, than the one usually employed, viz., of washing and staining the fine flocculi projecting from the deep surface of the pia mater of the cerebrum.

Spermatozoa.—It is convenient to select the spermatozoa of the Newt and Rat, the former on account of their large size, and the latter because of their peculiar shaped head. Dry cover-glass preparations are made in the way already described, stained in methylene blue, and mounted in balsam.

This is one of the best methods of showing how different physically the head is from the tail or cilium of a spermatozoon. The heads of the spermatozoa alone are deeply stained with the methylene blue, so that on looking at the preparation one sees only the bright blue heads. If it is desired the tail may be stained with eosin coloured with clove-oil after dehydration in alcohol.

A very excellent method is to stain the Newt's spermatozoa in Biondi's fluid already referred to. By means of it the heads are stained of a reddish purple, the tail red, and the spiral filament also red, while the little junction piece, where the head joins the tail, is red also, but deeper in tint than either the tail or the spiral fibre. By this differentiation in staining the differences in the physical and chemical constitution of the several parts of a spermatozoon are readily demonstrated. The method is one which is obviously capable of great extension in its application, and it can be applied with success to the study of other organs and tissues besides those mentioned.

HEREDITARY MALFORMATION OF DIGITS.

By J. WILKIE, B.A., B.Sc.

THE following cases occurring in a Lincolnshire country practice, may prove of interest :—

A, an infant, *æt.* 20 months, girl, otherwise in all respects well formed but rickety, suffers from the following digital and pedal deformity :—

Left Hand.—Broad thumb, with longitudinal furrow on nail, due to fusion of two nails. Index finger possessing first and second phalanges only without a nail. Second and third fingers possessing only proximal phalanges, joined partially but with double nail. Fourth finger (little), two proximal phalanges.

Right Hand.—Thumb and index fingers as above. Second (middle) finger, two proximal joints with nail. Third finger, two proximal joints, the distal joint represented by a fleshy pendant as large as a small marble, carrying a nail. Fourth finger, two proximal phalanges with abortive nail $\frac{1}{4}$ inch long and one line wide.

The two feet are alike, deformed as follows :—Hallux normal. First, second, and third toes abortive, with rudimentary transverse furrow for nail. Fourth (little) toe normal.

A has two sisters older than herself, the eldest (*æt.* 4) having similar malformation, but not identical; the other having hands and feet quite normal.

The mother of these children is similarly malformed in hands and feet, though otherwise a fine healthy woman. Her husband, of another stock, is quite healthy.

B, an infant boy, 12 months old, only child of his father and mother (the latter is sister of the mother of A), otherwise healthy, is afflicted with the following symmetrical malformation of hands and feet :—

Hands.—Thumbs broad, with double nail. First (index) finger proximal phalanx only with rudimentary nail. Second and third (middle and ring) fingers each only proximal phalanx, the two fingers being joined by a web. Fourth (little finger), two joints and a rudimentary nail.

Feet.—Great toes normal, all the others being short and rudimentary.

The infant's father is normally formed; and all in a family, by a previous marriage, are normally formed. His mother, he

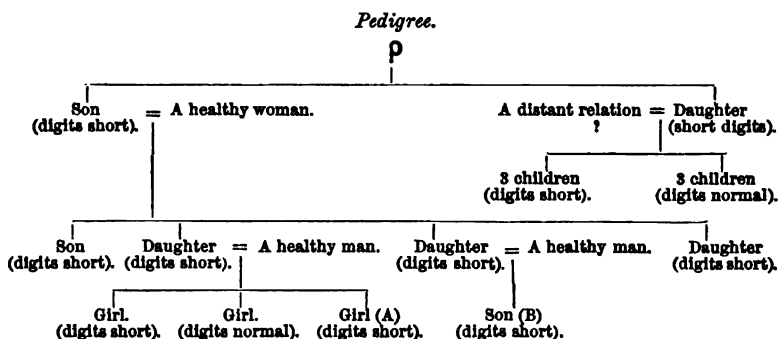
being her only child, has short fingers and toes, the fingers, where they have two joints, having a long proximal and a short second phalanx. This woman is otherwise well-formed, and of very prepossessing appearance.

Thus the two sisters, mothers of A and B, have transmitted to their children, with one exception, a remarkable deformity. They have another sister and a brother, both unmarried, also having short fingers and toes.

The father likewise of this family of four, the grandfather of A and B, and his one sister, he having no brothers, are similarly afflicted. This sister, married to a distant blood relation of her own, has a family of six, three malformed, three healthy.

The mothers of A and B, who gave us this account, say that the malformation runs far back into their ancestry, so that they cannot trace it. The tradition is, that one day a gipsy woman, who was pregnant, came to the house of a female ancestor of theirs, also pregnant, as the latter was gathering cherries, and asked for some. The woman said, "May my fingers drop off if I do!" and her child was the first in the family born with this deformity.

These evidences of similar malformation in three generations of one family, with account of the like in preceding generations, seem worthy of record. It may be observed that the members of this family, of which a pedigree is given below, while themselves residing in the same town, have distant blood-relations in other towns malformed in much the same way.



CONTRIBUTIONS TO THE COMPARATIVE OSTEOLOGY OF ARCTIC AND SUB-ARCTIC WATER-BIRDS. PART VI. By R. W. SHUFELDT, M.D., C.M.Z.S. (PLATES XI, XII.)

(Continued from page 116.)

Observations upon the Osteology of the Loons and Grebes.

As I have already stated in a former Part of this series of memoirs, the Committee of the American Ornithologists' Union on Classification of the Birds of North America, as set forth in our official *Check-List*, placed the Grebes (*Podicipidæ*) in a Suborder by themselves in the Order PYGPODES, while the Loons (*Urinatoridæ*) were relegated to another Suborder (the *Cepphi*) along with the Auks. Now, my studies of the works of Marsh upon the fossil *Hesperornis*, in his *Odontornithes*, convince me of the fact that, however widely separated now, our existing Loons and Grebes are derived from the same ancestral stock to which *H. regalis* belonged. A glance at the pelves, pelvic limbs, and other parts alone, is sufficient to impress us, I should think, with the probability of this affinity; so that it was with considerable surprise that I saw the arrangement to which I have alluded above adopted by the Committee of the Union, and I cannot believe that the classification there set forth for these forms will be supported by the characters of the skeletons when we come to compare them. Now, although I will, as I have in the case of the *Alcidæ*, avail myself of the specific nomenclature of these birds proposed by the Union, my notions of their affinities may prove to be very different. At any rate, at first sight I cannot understand placing a family containing *Urinator imber* next to a family containing *Lunda cirrhata*, and both in the same Suborder. Would that all of the families of birds were so well characterised!

Although my material is not very extensive for the study of the osteology of the Divers, still I hope it will fully meet the object we have in view and the requirements of a fair comparison.

Many of the osteological characters of the Grebes are well known, and have been utilised in classification. Coues, in distinguishing them from the *Urinatoridæ*, says that they have "the greater number of cervical vertebræ (19 instead of 13), and shortness of the sternum, with lateral processes reaching beyond the transverse main part (the reverse of the case in the Loons). There is a long cnemial process of the tibia reaching high above the knee-joint, backed by a large patella of about equal altitude" (Key, *North American Birds*, 2nd ed., p. 792). These latter characters are accompanied by a figure of the knee-joint (fig. 530 *bis*) which I drew for the author, being a copy of my figure of the same parts which appeared in the seventh volume of the *Proceedings of the United States National Museum* (fig. 3). The latter, however, gives the entire leg bones of *Podiceps cornutum* in two different positions, showing the extraordinary patella of the Grebes.

For the Grebes, I find I have at my disposal the complete skeleton of *Podilymbus podiceps*, collected for me at Fort Wingate, New Mexico, during the summer of 1885; also a specimen belonging to the Smithsonian Institution of *Aechmophorus occidentalis* from California. Unfortunately, it has the skull and limbs both missing, and is evidently the dried body of a specimen that has been taken from a bird to save the skin.

I find a specimen of *Colymbus nigricollis californicus* in my own private collection of skeletons. I am sorry to say, though, that the skull of this specimen was badly shattered by shot at the time of its capture. Enough of it remains to show, however, that the crotaphyte fossæ merely meet the outer boundaries of the occipital prominence, but the back of the skull is smooth externally, and unmarked by ridges or crests as in the Loons. Another feature is the narrow and quite superficial markings of the super-orbital glandular depressions at the posterior halves of the orbital peripheries. The true orbital margins here seem to have been long absorbed, the transverse diameter of the fronto-interorbital region being as narrow as in some of the Auklets.

This Grebe has 49 vertebræ in its column; the 19th bears

the first free pair of ribs, those on the 20th reach the sternum through costal ribs, as do the succeeding ones through the 26th inclusive, as well as the first vertebra that anchyloses with the pelvic bones. Nine free vertebrae and a pygostyle compose the tail of this bird, and when they are articulated *in situ*, they form a peculiar sigmoid curve, dipping downwards then upwards as the letter *J*. The ribs bear freely articulated epipleural appendages, but the outline of this bony framework of the thoracic parietes has almost entirely lost the peculiar form it has in the *Alcidae*.

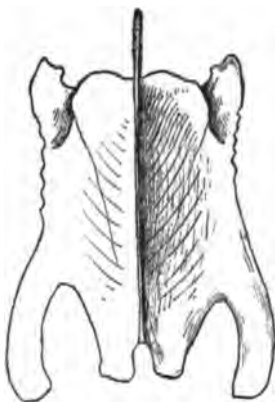


Fig.1.

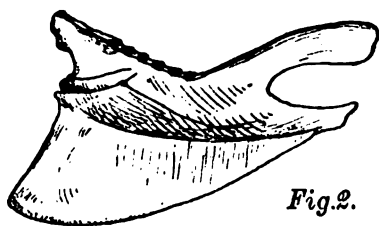


Fig.2.

FIG. 1.—The sternum of *Colymbus nigricollis californicus*, viewed from below.

FIG. 2.—Left lateral view of the same bone. Both figures life size, and drawn from a specimen by the author, in his own collection.

Two excellent figures of the pelvis of *A. occidentalis* are to be seen in Marsh's *Odontornithes*, on page 71, giving superior and lateral views. In them may be seen the unusually depressed position of the anterior iliac blades, allowing the

neural crest of the united sacral vertebræ to come into plain sight on lateral view, whereas posteriorly these iliac bones actually meet for some little distance over the top of the sacrum.

To show how the sternum of the Grebes differs from anything we found among the Auks, as well as from the form it assumes in the Loons, I here present two figures of it, one from the side and one from a ventral view (figs. 1 and 2). It will be seen that in it the coracoidal grooves are very deep, and nearly meet in the median line. Also, that the manubrium is aborted, its usual site being depressed. The walls of the sternal body enclose a marked concavity, which is greatly added to by the broad and spreading lateral xiphoidal processes. The mid-portion of this extremity may have a median notch in it, carried nearly or quite up to the hinder ending of the keel. This latter, as well as the costal processes, are well developed, and point to the possession of considerable power of flight on the part of the owner. It is interesting to compare the front view of this sternum with the same aspect of the sternum of the Eider Duck, and note the several points of resemblance.

In the pectoral arch, the *furcula* is of the U-form type of the bone, very slender, curved gently backwards towards the sternum, thoroughly united below, and showing a very small or sometimes no hypocleidum. The clavicular heads are carried out in tapering points to pass to the scapular heads in articulation of the arch, but they do not possess any facets to offer the other elements in so doing. A coracoid is very broad below, and the articular facets rise some little distance on this expanded end, both in front and behind, due to the depth to which this bone is sunk in its sternal bed when articulated in life.

The blade of the scapula is narrow for its entire length, and convex above, the reverse below, and with an exceedingly small scapular process of the coracoid for its head to rest upon.

The bones of the limbs, as well as those composing the other parts of the skeleton of *Colymbus*, are non-pneumatic. Humerus, radius and ulna, and the bones of manus are notable for their long slender shafts and slightly expanded proximal and distal ends. The form of the humerus differs entirely from that bone as we found it among the *Alcidae*. Its ulnar

and oblique tubercles are now placed upon the shaft, as in the vast majority of birds.

The morphology of the skeleton of the pelvic extremity of this Grebe is so well known, that I doubt my ability to add anything to our knowledge of it here. I would say, however, that I have observed that the hypotarsus of the tarso-metatarsus shows a longitudinal groove in the median line behind, and three vertical perforations through its body, a medio-anterior one, and one on either side and posterior to it. This entire piece seems to ossify from not more than one centre, and in the immature individual caps the proximal ends of the three metatarsals.

Podilymbus has a true Grebe's skeleton presenting many excellent generic characters to distinguish it from *Colymbus*. The skull differs not a little in its general form, and on top, posteriorly, shows faint indications of the crucial ridges as they are found in the Loons.

In this Grebe I find a long slender *vomer* in the skull, with forked hinder end, and terminated anteriorly by a round and horizontal disc of bone. The interorbital septum is entirely absent, and the brain-case very deficient in front. The foramen magnum is situated almost directly on the back of the skull, and its plane nearly at right angles with the basi crani.

In the sternum, we find the lateral xiphoidal processes far slenderer than they are in Grebes of the genus *Colymbus*, and considerably longer and more curved, otherwise the form of this bone is not very different.

The vertebral column and pelvis is that of a typical Grebe, and the latter would require but few changes to have it look like the miniature of that bone in the fossil *Hesperornis regalis*.

The skeleton of *Podilymbus* is almost entirely non-pneumatic; air seems to gain access only to certain parts of the skull, more especially its posterior moiety.

Observations upon the Osteology of the Urinatoridæ (the Loons).

As will be seen from the material loaned me by the Smithsonian Institution, in the subjoined list, we will be enabled to review with sufficient thoroughness the general characters in the skeletons of these Divers.

List of Material.

Specimen.	Locality.	Collector.	Smithsonian Collection, Catalogue Number.	Remarks.
<i>Urinator adamsii.</i>	Kodiak, Alaska.	F. Bischoff.	9,862	Sternum.
<i>Urinator adamsii.</i>	Arctic America.	Dr G. R. Horner.	15,341	Skull.
<i>Urinator lumme.</i>	Amchitka, Alaska.	W. H. Dall.	13,646	Skeleton.
<i>Urinator lumme.</i>	Wood's Holl, Mass.	V. N. Edwards.	16,628	Skeleton.
<i>Urinator pacificus.</i>	Pt. Barrow, Alaska.	Lieut. P. H. Ray.	16,733	Sternum and pect. arch.
<i>Urinator lumme.</i>	Pt. Barrow, Alaska.	Lieut. P. H. Ray.	16,734	Sternum and pect. arch.

Two notable papers have appeared in this country upon the osteology of *Urinator*, and both of these from the pen of Professor Elliott Coues, the one entitled "The Crania of *Colymbus torquatus* and *Colymbus adamsii* Compared" (*Proc. Acad. Nat. Sci. Phila.*, xvi, 1864, pp. 21, 22); the other "The Osteology of *Colymbus torquatus*, with Notes upon its Myology" (*Mem. Bost. Soc. Nat. Hist.*, i. pt. ii. art. 1, April 1866).

The first of these papers, at the present writing, is not at my hand; but I fortunately have a copy of the second one, and it will not only lighten my labours in the present connection, but, from its thorough treatment of many parts of the skeleton of the Loon, render it unnecessary for me to dwell at length upon the osteology of that bird, so that my attention will be turned principally to the skeleton of *U. lumme*, which presents at least some few notable differences in it when compared with the subject of Dr Coues' memoir. I have, too, devoted quite a number of the figures in the plates to the osteology of the Red-throated Diver, and in view of the importance which properly attaches to the knowledge of the structure of these forms, my hopes are that my labour has not been in vain.

Huxley says in his *Classification of Birds* that "the *Colymbidæ* appear to be closely connected on the one hand with the Gulls and on the other more remotely, but still really, with the Rails."

No doubt the knowledge of the osteology of these three groups possessed by this eminent anatomist brought to his mind

this conviction. The scope of the present memoir forbids me taking into consideration the osteology of the *Rallidæ*, but special pains have been taken to present the principal parts of the skeleton of quite a number of the *Laridæ*, so the reader may have the opportunity of at least making a few comparisons between these and the *Urinatoridæ* for himself.

Of the Skull (see Plate XI. of this Part, and fig. 7 Plate II., Part I.).—We find the superior mandible tapering gradually to a sharp point in the Red-throated Diver, with an evenly rounded convex culmen. This part has a peculiar upward tip that is not found in *U. imber*, and in the *Laridæ* its extremity is hooked.

The region of the cranio-facies is depressed, markedly so in the Loon, and the sutures between the nasal processes of the premaxillary and the nasals are distinctly seen in the adult.

The *Urinatoridæ* are holorhinal birds, and the dentary process of the nasal dips downwards and forwards at a gentle curve, thus including the large and somewhat elliptical osseous nares. There is no bony nasal septum. Each lacrymal articulates to a very limited extent with the corresponding frontal, and almost entirely with the outer margin of the nasal. Its descending process nearly meets the jugal bar. In the Gulls this process is much shorter, and is bent backwards to ankylose (usually) with the pars plana; in the *Urinatoridæ* the pars plana does not form in bone, and the mesethmoidal plate is thin, showing a raised welt at the usual site of the base of this wing where it occurs in the other groups.

A large vacuity is seen in the middle of the interorbital septum, but the optic and other foramina for exit of nerves from the brain-case usually retain their integrity. The track of the olfactory nerve is commonly roofed over for its posterior third or more by an extension of the bony wall which covers the anterior aspect of the rhinencephalon. This arrangement is not seen in a specimen of the skull of *Larus glaucus*, and its interorbital septum is quite thick and entire.

The *quadrate* has a long, plate-like, and upturned orbital process, and two prominent facets upon its mandibular foot, they being about on the same level.

Regarding the skull of any of the *Urinatoridæ* from above, the most striking feature that meets our eye are the deep,

sharply-defined, supraorbital glandular depressions. These are extensively perforated by minute foramina over their posterior halves, while a large irregular foramen occurs at each anterior end. Over the frontals they are separated by a thin crest of bone in the median line, while their posterior halves curve regularly outwards, to extend upon each roof-like post-frontal projection. In *U. imber* we find them giving rise to a raised superior orbital margin, connecting the lacrymal and the aforesaid post-frontal projection, as we saw it in *Alca* and *Uria*. *Urinator lumme* has this rim incomplete sometimes. Fully as striking in character to these supraorbital depressions are the extraordinary crotaphyte fossæ. These are very broad antero-posteriorly, and strongly-marked throughout. On the top of the skull they are separated from each other by a raised and median line of bone, being the simple backward extension of that smooth central area of the vault, which has remained unmutated by depressions. From this these fossæ sweep on either side in increasing depth downwards and forwards beneath the overhanging post-frontal roof and over the top of the external auditory wing.

Viewing the skull of the Red-throated Diver from behind (Plate II., Part I., fig. 7), we find that the large dome-like supra-occipital prominence is overlapped by these broad crotaphyte fossæ, and the median line separating them is extended directly backwards as far as the superior margin of the foramen magnum. This prominence is also transversely crossed about its middle by the raised crest that separates the crotaphyte fossæ from the occipital area. The plane of the foramen magnum is nearly vertical, and the reniform condyle projects directly backward from a thick-set pedicle, its convex surface being inferior.

It is very evident that this posterior aspect of a Diver's skull resembles much less the same view of the skull of any of the *Laridæ* than *Alca* does; indeed, the posterior view of the skull of the Razor-bill very closely resembles a like view of the skull in several of the Gulls.

On the under side of the skull of *Urinator lumme* we find the arrangement of the palate and other elements agreeing in all essential particulars with the Gulls, Auks, or Guillemots; in

other words its structure is that of a typical Cecomorph of Huxley's classification, so far as these parts are concerned.

In a well-cleaned skull the palatines can easily be traced to their anterior endings, and this is equally true of the Loon. Behind they are long and narrow, showing a double carination with a concavity dividing them. This is again divided by a transverse ridge near the middle of the body of each bone on its under side. The ascending processes of the palatines are grasped by the hinder ends of the vomer, and between them both rides the thin inferior edge of the rostrum. Anteriorly the vomer among the *Urinatoridæ* inclines to become pointed, while above it is longitudinally grooved for its entire length, and the edges of this groove are handsomely curled outwards.

The maxillo-palatines are thin concavo-convex plates raised above the horizontal portions of the maxillaries, and otherwise arranged as in the *Alcidæ* and *Laridæ*.

The posterior heads of the palatines are in contact, and form a groove between them above for the rostral bar of the pre-sphenoid as usual. They are grasped in a peculiar manner by the anterior ends of the pterygoids, which are fashioned like little two-toed feet to seize them, the larger claw being above and the smaller one below, the seizure being of such a nature as to limit the motion to a fore and aft one. Coues noticed this arrangement in the Loon, and alludes to it in his memoir. The posterior end of each pterygoid is much enlarged and makes an extensive articulation with the quadrate of the corresponding side.

Foramen ovale opens quite laterally in the Red-throated Diver, and still more so in the Loon, and the posterior wall of each orbit is marked by an outwardly concave, nearly vertical ridge, which seems to limit the depression of the crotaphyte fossa upon that aspect on either side. Among these Divers the *mandible* is very much alike.

It is fashioned so as to be in harmonious keeping with the form of the superior one, being carried to a sharp point anteriorly by a gradual tapering in that direction. Opposite the posterior ends of the dentary each ramal side is deep from above, downwards, and the vacuity found in other birds upon this surface is completely closed in by the mandibular ele-

ments of the vicinity, the splenial and dentary, principally the latter.

As among the *Alcidæ*, however, we find a large elliptical foramen in the surangular in most Divers, but rather a small one in the Loon in the same situation. Both the upper and lower ramal borders are rounded, and the coronoid processes fairly well developed.

Viewed from above, we find the mandible to be V-shaped, with rather a short symphysis. The articulate facets for the quadrate are large and included in a squarish area in each mandibular end. Each angle is truncate from above, downwards and backwards, its emarginated lateral borders behind, enclosing a rather deep concavity, seen upon direct posterior aspect. Now the outer of these two borders on either ramal angle, is produced upwards, forwards, and outwards as quite a prominent peg-like process. Thus I consider the angles of this mandible as being both truncate and recurved, and it is easy to conceive how by gradual steps this condition in the *Urinatoridæ* could be so modified as to have the truncation subordinated or even disappear, while the process became the feature of the mandibular angle, as in such a form as *Lunda cirrata*, wherein but little further change is required to produce the process as found in the *Gallinæ*. The mandible of *Larus glaucus* before me has no such process whatever, and even the parts that give rise to it are not present, the mandibular ends being reduced to their simple requirements for articulation with the quadrates, whereas these truncate parts in the Diver are evidently added to, and amalgamated with these articular cups behind.

The skull and mandible in the *Urinatoridæ* are non-pneumatic.

I regret very much to find that the *hyoid arches* belonging to the skeletons of these Divers in my hands have been unfortunately lost, and I am unable to say anything about their structure in these birds from personal investigation.

A complete skeleton of *Urinator lumme* (No. 13,646 Smithsonian Collection) before me I find has 43 vertebræ in its spinal column. Of these the *fourteenth* is the first to bear a pair of free ribs; the succeeding six movable vertebræ connect with the sternum by costal ribs; the next seventeen unite as a "sacrum"

with the pelvic bones; then follow six free caudals and a pygostyle containing probably several more.

The character of these vertebræ in the anterior cervical region is shown in figure 32, Plate V., in Part I., and for the dorsal region on Plate IV. of the same Part.

The dorsal ribs are broad, and bear large, freely articulated epipleural appendages. Two pairs of ribs also come from the sacrum, and meet long, sweeping hæmapophyses, that reach the costal borders of the sternum. This specimen has also a "floating costal rib," which is very small and delicate. It is seen on both sides. The form of the skeleton of the thoracic parietes recalls to some extent the shape it assumes in the *Alcidæ*, with its hinder ribs sweeping beneath the pelvis. This latter bone (Pl. XII. figs. 8 and 9) is of extraordinary form and dimensions in all of the *Urinatoridæ*, even excelling the Grebes in the quaintness of its style. The anterior portion of an ilium is short and depressed in comparison with its extensive reach behind. The neural crest of the sacrum appears above the pelvic bones for its entire length, and posterior to the large elliptical ischial foramen the ilium looks directly outwards, then outwards and upwards. A small prepubis is present, while the post-pubic element is long and slender, its posterior extremity, curving beneath the pelvis behind, is dilated and paddle-shaped. It nearly meets the fellow of the opposite side, where both are finished off by an emargination of cartilage.

Five of the last caudal vertebræ, together with the pygostyle, are shown upon their side view in Plate XII. fig. 7. The three first chevron bones there exhibited are freely articulated over the joints of the centra when they appear; the ultimate ones, however, become ankylosed to the under side of the rear vertebra in each case, the last one really forming the antero-inferior process of the pygostyle.

A clavicle of the *pectoral arch* (Pl. IX., Part II., fig. 15) has a broad head, but is as thin as a knife blade, the outer aspect of which, when articulated, it simply rests against the summit of the coracoid, while its posterior end rides over the head of the scapula. This expanded part of the clavicle rapidly contracts in width as it descends, until it becomes quite rod-like, square

on section, to curve abruptly towards the sternum, where it unites with the fellow of the opposite side to support in the median line rather a long, peg-like hypocleidium. Viewed from in front, the furcula is a wide U-shaped bone, with its lower arc curved more than usually upwards. In common with other bones of the arch, it is non-pneumatic.

The lower part of a *coracoid* is much expanded lateral-wise, with smooth and evenly concave articular lower margin for the sternal groove. As in some of the Auks, the lower lateral margin of the bone develops a prominent upturned laminated process. The shaft of the coracoid is transversely elliptical on section, and its scapular process may, or may not descend, upon its inner side, sufficiently far as to be pierced by the foramen which was likewise described for the *Alcidae*. The head rears to a considerable extent above the glenoid cavity, and its tuberosus summit curls over towards the median plane.

Larus glaucus possesses a coracoid that has the foramen in the scapular process, as well as the laminated externo-lateral apophysis as in *Urinator*, but its *furcula* resembles that bone as we found it in the Auks and Guillemots.

The *scapula* in the Red-throated Diver is short, and doubly truncate behind. Its curvature may be quite abrupt just beyond the head in some specimens. This latter is transversely narrow, and thickened from above, downwards; it occupies the entire upper margin of the scapular process of the coracoid.

In the Yellow-billed Loon, when the pectoral arch is articulated *in situ*, if the line of the long axis of the coracoid were produced downwards it would cut the lower margin of the keel of the sternum at the junction of its middle and anterior thirds; the *scapulæ* are much tilted upwards, and the aborted hypocleidium of the furcula is over the tip of the carinal angle and separated from it by about a centimeter.

Among the *Urinatoridæ* the *sternum* (a figure of the pectoral aspect of this bone is given on Plate VIII, fig. 7, Part II., and its side view will be figured later on) is comparatively a very large bone, even when compared with the sternum of the other species of the same genus. It is twice as long as it is broad, with large triangular costal processes. An extensive rounded notch on either side gives rise to lateral and

xiphoidal processes, while the mid-portion of this posterior part is continued in membrane, and in the prepared skeleton may show a number of irregular foramina of no great size. The keel is very low and extends far back, when it gradually merges into this mid-process behind, but some little distance anterior to its termination. As a rule eight facets are formed upon each costal border, and the manubrium is much aborted and barely projects beyond the anterior border of the bone. In all Divers it is a non-pneumatic bone, though light and splendidly adapted to the economy of its owner.

Coues has described the sternum of *Urinator imber* in great detail.

Its form in *U. lumme*, as seen in specimen 16,734 (♀) of the Smithsonian Institution, reminds me much of the sternum as it is found among the *Alcidæ* in this particular specimen, which happens to be much narrower than the one I have figured, in fact, strikingly so. Very little remodelling would make it an Auk's sternum. But among these water-birds skeletal characters crop out very strangely sometimes, as for instance, there is no hiding the fact that the sternum of an Albatross, a Cormorant, *Plotus*, a Fulmar, and a Grebe all resemble each other not a little sometimes upon a direct pectoral view, and to a less extent in several of the forms, upon a lateral one.

Of the Pectoral Limb in the Divers.

(See the figures in the several Plates illustrating the Parts of these Memoirs.)

• All the bones of the upper extremity are non-pneumatic in this family. They are heavy, and when simply cleaned in the rough, they soon become dark and the oily substances contained in their cavities ooze out upon their outer surface in no inconsiderable amount.

The palmar aspect of the proximal end of the humerus has a large subcircular elevation upon it that is quite characteristic. This projects in such a manner that upon the reverse side it is seen extending beyond the border of the bone, near the shallow, pseudo-pneumatic fossa.

The radial crest from its size and length is more than usually conspicuous; its free border is a long convexity, and this plate-

like process is carried well down the shaft, occupying fully one-third of its length. Below it the shaft for its middle third becomes subcylindrical, showing a large nutrient foramen upon its ulnar aspect.

The distal end of the bone is not spread much in a transverse direction, but otherwise rather bulky. Two wide and shallow furrows mark it on the anconal side for the passage of tendons, and a large oblique and ulnar trochlea stand out upon the other. The ectocondyloid process is barely noticeable.

The *radius* is straight, and the major part of its shaft nearly cylindrical; its articular ends present the characters of the bone as seen in the majority of the class. When articulated these alone meet the ulna, giving rise to a long narrow interosseous space. Towards this the larger bone of the antibrachium presents a concave border of a moderate degree of curvature. Its shaft, too, is quite cylindrical, and faintly shows the row of papillæ for the quills of the secondaries. It develops in a transverse direction not an inconsiderable ledge at its distal end, upon which the expanded end of the radius rests in articulation.

The carpus is composed of the two elements found in most birds; they are here simply somewhat modified in form for the family, and to accommodate themselves to the shape of the other bones with which they come in contact, they in turn having their own specific cast.

One of the first things that forces itself upon our attention in examining the skeleton of the hand in this Diver is the unusual length (comparative length) of the metacarpals. Of these, the one for pollex digit is of an extraordinary length; much more than a third the length of the index one, and co-ossified with it in the usual manner.

I do not recall an instance among birds where the comparative lengths of these two metacarpals is anything like it. The proximal phalanx of pollex is also long and compressed. It bears a claw upon its extremity. Both of the other metacarpals are long and very straight, allowing but a narrow interval to exist between them.

The blade of the proximal phalanx of index is meagre, being flat anconad and faintly pitted upon the opposite side. Its distal joint also bears a claw.

The phalanx of the middle finger is fully half as long as the expanded one of index alongside of which it lies.

These observations upon the pectoral limit of the *Urinatoridæ* have been jotted down during my examination of this part of the skeleton in a specimen of *U. lumme*, and in it I find the skeleton of manus, just described, equalling in length the bones of the antibrachium.

The humerus in this Diver has a length of about 14.5 centimeters; the radius 11.4; the ulna 11.65; manus 11.8, of which latter the carpo-metacarpus claims 7.5 centimeters. From this it is seen that when the skeleton of the limb is in a position of rest and closed alongside the chest, the humerus projects beyond the bones of the antibrachium for some little distance. Turning to fig. 89, we observe that this is not the case among the *Laridæ*, whereas it agrees with *Alca torda*, *Uria*, and I expect the *Alcidæ* generally.

Of the Pelvic Limb in the Urinatoridæ.

(Figures of the bones of this limb will be published in a Plate in a subsequent Part.)

The skeleton of the pelvic limb in the *Urinatoridæ* is a very interesting structure, and highly characteristic of the family.

Dr Coues has admirably described its mechanism and structure in *U. imber* in his memoir before alluded to, and it will only be necessary for me here to record a few observations that I have made upon this limb as found in *Urinator lumme*.

The femur is short and thick, being about as long as the cnemial process of the tibio-tarsus above the articulation. Its short shaft is somewhat cylindrical near the middle, bowed to the front, and scarred in many places by tuberos projections for muscular insertion. The head is large and globular, sessile, and deeply marked by the pit for the ligamentum teres. Distally, it is much expanded in a transverse direction, the inner condyle being small and elevated, the outer one being very large, strongly cleft behind for the fibular head, much the lower of the two, and separated from its companion in front by a deep rotular fossa.

The *patella* of the Red-throated Diver is a flake-like bone

articulating at the posterior base of the cnemial process of the tibia. Its form and exact position I have set forth in my paper upon the patella in birds in the *Proceedings of the United States National Museum*, vol. vii. p. 328, fig. 4. This illustration also presents the outer aspect of the femur, tibio-tarsus, and fibula; the latter two for their proximal two-thirds only.

Nothing could be more interesting than the form assumed by the tibio-tarsus of this Diver. Its cnemial process is enormously produced, having a deep, longitudinal concavity between its pro- and ecto-cnemial ridges in front, and the two sides meeting in a median ridge behind. The pro-cnemial ridge is carried down as a wing for some distance on the side of the shaft. This latter is somewhat flattened from before backwards for its entire length, but better marked in this particular at its distal extremity, just before we arrive at the condyles, where also it is marked by the broad, shallow tendinal groove. This is bridged over by the usual bony span for the deep extensors.

The condyles are very prominent in front, but approach each other as low, sharp ridges behind. Coues found the fibula in the Loon, "for an inch or so, quite separate from the tibia; is then united with it for some distance, becomes again distinct for about an inch, and then finally merges as a slender spiculum into the side of the tibia, rather more than an inch above the joint. A slight crest, however, gives an indication of it, which can be traced quite to the external malleolus of the tibia." This description agrees with one of the specimens before of *U. lumme*, but in another it is carried down distinct and prominent to terminate in a well-formed malleolus upon the lower antero-lateral aspect of the shaft. The lower portion is ankylosed with the tibio-tarsus, but could, with but little difficulty, be separated from it with a good sharp knife.

Four figures have been devoted to the extraordinary tarso-metatarsus of the *Urinatoridæ* as seen in *U. lumme*. These give various aspects of the bone, and distinctly show all the characters it possesses. Chief among these is the great amount of lateral compression of the shaft and trochlear end. The former is grooved both in front and behind for its entire length, forming a guide as well as a harbour for the passage of tendons.

The hypotarsus is very large, it being composed of a posterior

arcade of bone with three distinct foramina piercing its substance in front of it. Occupying a position above the base of the mid-trochlea, the inner one of these three compressed protuberances projects the most posteriorly. The remaining two are separated by a cleft, which is continued above by a groove on the anterior surface, to be pierced obliquely from above, downwards, by the usual arterial foramen. The mid-trochlea is the lowest of all three, and rather the most anterior. They are all strongly marked by median grooves intended for the corresponding surface on each proximal phalanx of the digits.

A scale-like first metatarsal is suspended by ligament attached to its entire anterior free border, to the inner inferior posterior margin of the shaft of the bone. It supports a feebly developed phalanx and claw representing the hallux digit. As for the three anterior toes, they are composed upon the usual formula for the number of joints as found in this member in the majority of the class. All of the ungual phalanges are in this Diver flat and scale-like.

The proportionate lengths of these joints in the skeleton of pes are shown in the following measurements:—Hallux joint has a length of but 1.1 centimeters, its claw but 0.5; the proximal phalanx of the inside toe measures 4.0 centimeters, the next joint 2.1, and its claw 0.95. The proximal joint of the middle toe 3.6, next joint 2.0, next 1.8, the claw 0.9; finally the proximal joint of the outside toe 2.8, next 1.6, next 1.4, next 1.8, and the claw 0.85.

Aside from the osteology and other interesting points of structure in the pelvic limb of this Red-throated Diver, an engaging feature is to be noticed in the great number of fibrous loops attached to the long bones at a number of points, which serve to surround and guide the various tendons on their passage to the toes and prevent them from slipping from their places as they pass these narrow bones, when the limb is brought into vigorous action.

Brief Summary of the Principal Osteological Characters of the Urinatoridæ.

There will be presented here simply such characters as distinguish the *Urinatoridæ*, and those which, as a rule, are not

characteristic of allied groups, as the *Laridæ*, *Alcidæ*, and others.

1. Holorhinal birds, with superior mandible spear-shaped, tapering gradually to a sharp apex.
2. Anterior ends of pterygoids distinctly two-clawed, fashioned to firmly seize the heads of the palatines, nearly surrounding them.

Crotaphyte fossæ divided by a median *line*, which equals in length the descending maxillary process of a nasal. (As a negative character of the skull, we find the *pars plana* on either side absent.)

3. Clavicular heads are broad vertical plates, very thin, and simply resting, in each case, against the inner aspects of the heads of the coracoids, while posteriorly their ends ride well over the heads of the scapulæ. For the rest, the lower parts of the furcula are far more feebly developed. (Differs from the Grebes, Gulls, and Auks.)
4. Pelvis *extremely* long and narrow; a small prepubis present; post-pubis slender, but broadly paddle-shaped behind, where it nearly meets fellow of opposite side.
5. Pollex metacarpal very long; equal to a third of the shaft of the index metacarpal, to which it is anchylosed as usual.
6. Femur short, only equals in length the greatly produced cnemial process of tibio-tarsus; patella, small and flake-like; fibula may be complete, with its lower third or more anchylosed to the other leg bone.
7. Shaft and trochleæ of tarso-metatarsus very much compressed lateral-wise; first metatarsal free and flake-like; proximal joint of hallux less than a third the length of proximal phalanx of inside digit of pes.

Before stating my views upon the taxonomy of the Order PYGOPODES, as it seems to be indicated through my studies of the osteology of the various genera composing it, I would first devote a chapter to the review of some of the American forms of the succeeding group, or the Order LONGIPENNES.

This will place at our command an array of skeletal characters presented by the Laridine types, which, in many instances, show but a slight departure from the forms we have just been con-

sidering, and consequently will lend additional light to the suggestions I have to offer upon the classification of the two Orders in a later Part in these memoirs.

EXPLANATION OF PLATES XI., XII.

[*Note*.—A number of the figures of the skeleton in the Red-throated Diver have already appeared in the Plates of foregoing Parts, which figures have been referred to and described in the present paper, while in a subsequent Part it is my intention to figure the lateral view of the sternum of this bird, and present drawings of the bones of the pelvic limb. The figures of the pelvis and sternum here given of a Plover will be alluded to in the description of the skeletons of the Gulls, &c., later on.]

PLATE XI.

Fig. 1. Skull of *Urinator lumme*, right lateral view; life size.

Fig. 2. Mandible of *Urinator lumme*, viewed from above; life size.

Fig. 3. Skull of *Urinator lumme*, superior view; life size, with the mandible removed.

Fig. 4. Skull of *Urinator lumme*, basal view, mandible removed; life size. These four figures, drawn by the author from a specimen taken at Wood's Holl, Massachusetts, and now numbered 16,628 in the collection of the Smithsonian Institution.

PLATE XII.

Fig. 5. Pelvis of *Charadrius dominicus*, viewed from above; life size (specimen No. 16,715 collection of the Smithsonian Institution. Collected by the Point Barrow Expedition of 1882 in Alaska). By the author.

Fig. 6. Sternum of *Charadrius dominicus*, pectoral aspect; life size. By the author, from the same specimen as furnished the pelvis for fig. 5.

Fig. 7. Caudal vertebrae and pygostyle of *Urinator lumme*, right side view; life size.

Fig. 8. Pelvis of *Urinator lumme*, superior view; life size.

Fig. 9. Pelvis of *Urinator lumme*, right lateral view; life size. Figs. 7, 8, and 9 were drawn by the author from specimen 16,628 (Smithsonian Collection), the same skeleton which furnished the skull for Plate XI. of this Part.

THE STOMACH OF THE NARWHAL: THE BEARING
OF ITS HISTOLOGY ON TURNER'S AND MAX
WEBER'S NOMENCLATURE OF THE STOMACH
OF THE ZIPHIROID AND DELPHINOID WHALES.
By G. SIMS WOODHEAD, M.D., and R. W. GRAY, *Student
of Medicine, University of Edinburgh.*¹

IN a communication we gave before the Royal Society of Edinburgh last winter, we described somewhat minutely the histological structure of the stomach of the Narwhal (*Monodon monoceros*). When it was written we had not read either Professor Sir W. Turner's paper² or Professor Max Weber's paper,³ in both of which most valuable information and generalisations on the stomach of the cetaceans are given.

It is evident on reference to the three papers that, although the main facts and observations in all are interpreted in much the same manner, there are slight differences of opinion amongst the observers on some of the minor points. Cetological writers from the time of Tyson⁴ are agreed in describing the first division of the stomach in the Delphinidæ as a diverticulum, prolongation, or expansion of the œsophagus. Turner and Max Weber have stated that in the cetaceans, with the exception of the Ziphioids, the stomach is divided into what may be called an œsophageal portion and a true stomach; but there is some difference of opinion as to the methods of division and nomenclature to be adopted in describing this true stomach.

The first compartment, or œsophageal diverticulum, retains all the histological elements and structure of the upper part of the œsophagus. The mucous membrane is thick, the horny cells are arranged in regular lamellæ, and the deeper cells are polygonal. The structures described by Turner in the Porpoise

¹ The substance of this paper was given before the British Association at the meeting held in Newcastle, September 1889.

² "Additional Observations on the Stomach in the Ziphioid and Delphinoid Whales," *Jour. Anat. and Phys.*, vol. xxiii. p. 466 *et seq.*

³ *Morph. Jahr.*, 1887-88, p. 637 *et seq.*

⁴ *The Anatomy of a Porpoise*, 1680.

as folds we find to be true papillæ in the Narwhal, which appear to project upwards as delicate filiform processes, ramifying somewhat irregularly. This irregular ramification is sometimes so marked that masses of epithelium seem to be cut off; these then appear to be very like gland acini, for which, in allied species, they have by some observers been mistaken.

We assigned to this cavity a function which has been most aptly termed "maceration" by Turner in the paper above referred to. He speaks of this first portion of the digestive apparatus as a "macerating chamber;" and we pointed out that it was a cavity in which food might be mixed with gastric juice, and from which hard parts of crustaceans and other indigestible matter might be strained out and ejected through the wide opening of the œsophagus.

In regard to the second compartment, or first true digestive cavity, there is also a general agreement.

It is always spoken of as the cardiac or proximal division, or as corresponding with the fundus ventriculi. For convenience of reference, the former is, perhaps, the better term. The glands in the thick mucous membrane of this cavity are closely packed together, and are very numerous. The secreting portion of the walls of these glands is formed by a double layer of cells—a central or columnar layer near the mouth of the duct, the cells of which, however, are more cubical in the deeper portion of the gland. Outside this is a second or parietal layer completely investing the tubule (and not occurring at intervals as in the cardiac glands of the stomach of the Dog and human subject, and as described and figured in other cetaceans by Max Weber). These cells are large, nucleated, granular protoplasts, irregular in shape, slightly flattened or pyramidal, and each lodged in a distinct cavity formed by a framework of delicate connective tissue, on the strands of which small flattened nuclei are seen. This reticulation corresponds, apparently, to that in the same position in the Pig and the Porpoise (described by Heidenhain). It appeared at first sight as though the large parietal cells were entirely surrounded by the delicate strands, but, on more careful examination, we came to the conclusion that there is a small orifice in the inner wall of the space through which the two sets of cells are brought into direct communication. Turner also

speaks of these different forms of cells, and demonstrated them even in specimens very imperfectly preserved for microscopic examination.

In addition to the slight difference above mentioned, the descriptions we gave of the glands of this first true digestive cavity differs from those given by Turner in the Porpoise and Max Weber in *Lagenorhynchus* and *Phocæna* in a somewhat important point. We speak of them as simple unbranched tubes, each continued downwards from a duct of its own, running straight from the surface to the submucosa, where it ends in a short hooked extremity.

After reading Max Weber's description we thought that perhaps the divisions he describes as occurring at the junction of the middle and lower third of the tube, or sometimes lower down, had been overlooked by us, but, after most careful re-examination, we found no trace of any such division. In order to make sure, we counted, time after time and under different magnifying powers, the number of ducts in a field, first at the surface, and then just above the hooked extremity close to the submucosa, and we found that in no case did we get a difference of more than 4 per cent., so that, although we do not say that in *Monodon monoceros* there is no such division, we have certainly been unable to distinguish any.

The part of the stomach after this is apparently somewhat differently described and named by different authors. Max Weber, Boulard and Pilliet¹ consider that the whole of the stomach after the cardiac portion should be considered as corresponding to the pyloric portion of the stomach of the carnivora. Max Weber says the glands are mucous, secreting, and that, in other respects, they are like those found in the carnivora. He goes on to say that the cetacean stomach can be compared, in some respects at least, with the form of stomach met with in the Pinnipedia, in which the pyloric portion is sharply defined from the cardiac.

Turner, on the other hand, basing his description and nomenclature on observations on a large number of species of both Ziphioid and Delphinoid Whales, divides this portion of the stomach into intermediate and distal or pyloric divisions.

¹ *Jour. de l'Anat. et Phys.*, 1884.

Although neither of these methods of division and naming, as given by these authors, is absolutely accurate so far as our observations go, we are inclined to look upon Turner's as the more convenient. In the first place, on examination of the next division, which we should have to call the second cardiac, first pyloric, or first intermediate division, it is found that at its cardiac end there are, in the deeper portions of the secreting glands, a number of the large parietal cells similar to those found in the cardiac glands; whilst at the distal portion of the cavity, there are found only ordinary columnar epithelial cells resting on a basement membrane of flattened nucleated cells. These columnar cells correspond to the pyloric or central cells. In this case, then, the cavity is certainly intermediate in character in whatever light it may be viewed. The two following divisions resemble one another very much in all respects. The glands are all lined by columnar or cubical epithelial cells, and in the deeper parts the secreting tubules branch, and are somewhat irregular in their mode of termination. Max Weber describes them as being somewhat convoluted at their lower extremities, the branches becoming entwined like two or three convolvulus stems growing together. We also have observed this in some cases, but we think that this structural appearance becomes more and more marked as we approach the pyloric end of the stomach, and reaches its highest development in the duodenal part of the intestine outside the stomach. These two last divisions, then, must, we think, be looked upon as the true pyloric part of the stomach, unless some characteristic and distinctive features can in future be found.

It would appear probable, from a careful study of Turner's descriptions, that in the Narwhal the intermediate portion is not so fully developed as in the Ziphioids, but that the pyloric portion is somewhat more complicated, and approaches more nearly the description given by Max Weber.

In this instance, however, there is not that sharp line of demarcation, at the junction of the cardiac and intermediate cavities, between the cardiac and pyloric glands. We find the former extending for some distance into the intermediate compartment, and we should say that Max Weber's comparison of the stomach with that of the Pinnipedia does not altogether

hold good. There is here a condition analogous to that found in the stomach of the Rat, in which the squamous œsophageal epithelium extends for some little distance into the cardiac cavity, *i.e.*, beyond the cardiac orifice.

In the Delphinoid cetaceans then, there is always an œsophageal paunch—Turner's macerating chamber. This is in no sense of the term gastric, but it serves as a storage and macerating cavity from which may be regurgitated refuse material. In both Ziphioids and Delphinoids there is a true distal or cardiac cavity lined with a layer of "cardiac" glands. Then follow what Turner calls the intermediate divisions, from his descriptions, numerous in Sowerby's Whale, fewer in *Hyperoodon rostratus*, and according to our observation present as a single small cavity only in the Narwhal. This division is followed by the single pyloric cavity according to Turner, but in the Narwhal by two divisions, both of which are lined by "pyloric" mucous membrane.

As there are no very full or accurate descriptions of the stomach of the Narwhal except those given by Meckel,¹ Turner,² and ourselves,³ we may point out that we could not agree with Turner that in this species the tubular glands are branching, but that we are able to endorse most fully his statement that these glands are of the cardiac type in form and arrangement. On reference to Turner's illustration,⁴ it will at once be seen that in this species the stomach is to all intents and purposes divided into four distinct portions, the first consisting of the œsophageal portion, with which the cardiac section is directly continuous; then follows the small cavity described by Murie⁵ as a communicating tube, but which we should with Turner prefer to call an intermediate compartment for the reasons above given; and lastly comes the pyloric division, which structurally and anatomically, as Turner's and our illustration show, is accurately named, although, in this instance, it appears to be made up of two compartments instead of a single one.

¹ *System der Vergleichende Anatomie*, vol. iv. p. 527, 1829.

² *Journal of Anatomy and Physiology*, vol. xxiii. p. 484.

³ *Proceedings Royal Society*, vol. xvi.

⁴ *Loc. cit.*, p. 485.

⁵ *Trans. Zool. Soc. Lond.*, viii., 1873.

Here then we have a most definite arrangement of the parts. We have a complex carnivorous stomach in which certain portions are specialised, as it were, for the performance of the different gastric functions. First, the œsophageal diverticulum, with its wide œsophageal orifice, sharply defined from the cardiac cavity. The work of this section is purely mechanical; it is provided with strong muscular walls and with powerful horny epithelial ridges and processes, which can perform the work of both grinders and strainers in a cavity in which the food is macerated along with the gastric juice from the cardiac cavity. The wide œsophageal orifice allows of ready ejection of hard and indigestible material, whilst the soft parts are readily passed along grooves and between papillæ to the cardiac orifice, or that of the first true stomach. In the cardiac cavity the process of digestion is continued, and here we have only the one form of gland corresponding in all essential details to the cardiac glands of carnivora, and differing only in the fact that the large peripheral cells are more closely packed together than in most other forms, and that the gland tubes are, as a rule, not so much [if at all] branched, as in the other forms hitherto described. In the next cavity, which is well named the intermediate portion of the stomach, the partially-digested food is received and is further mixed with gastric juice; but here the character of the secretion must be altered, as there now comes into play the pyloric form of gland which occupies the greater part of the mucous membrane at some little distance from the cardiac cavity, near which, however, a number of cardiac glands are found. In the next two cavities, *i.e.*, in the pyloric division, the glands are all of the pyloric variety, and are lined simply with axial or principal cells; here is completed the process commenced in the small intermediate division.

We have in the cetaceans, then, a high differentiation of the carnivorous form of stomach. In many of the herbivora, as is well known, the distribution of the so-called cardiac glands is extremely irregular, and they are in no way localised in certain parts of the stomach as they are in the carnivora. Consideration of this one fact enables us to say most definitely, were there no other proof existent, that the old idea that these Whale's stomachs are of the ruminant type is entirely without foundation.

In the case before us the differentiation and localisation have become so marked that the various kinds of glands are, with the single exception of those in the intermediate division, contained in separate cavities, in which each process of digestion is carried on by itself. This is the condition of affairs met with in the Narwhal. Max Weber has given us histological details of the structure of the gastric mucous membranes in other forms, but until we have a most careful examination of the mucous membrane from different parts of all the cavities in the various species, it will evidently be unsafe to generalise too widely, as, from what we have observed, it is impossible to bring the stomach of the Narwhal, entirely, under the classification given by either Turner or Max Weber.

THE ACTION OF VARIOUS STIMULI ON NON-STRIPED MUSCLE. By G. H. COOKE, M.R.C.S., *Platt Physiological Scholar, The Owens College, Manchester* (PLATE XIII.)

(From the Physiological Laboratory of the Owens College, Manchester.)

THIS contribution contains the results of an investigation undertaken to ascertain the action of various stimuli on the musculature of the stomach of the Frog.

The structure of the muscle contained in the walls of the Frog's stomach is that of the non-striated variety. Much more work has been done recently on striated than on non-striated muscle, hence the results of the former are much more widely known, so that it may not be out of place, before giving my own results, to give a short summary of the results of other observers.

Engelmann found that the ureter is capable of undergoing peristaltic movements—apart from any nervous influence—on stimulation, which persist after the cessation of the stimulus.

The results which Van Braam-Houckgeest and Ranvier, working on the alimentary canal of the Rabbit and Frog respectively, obtained are much alike. They are as follows:—

1. Certain parts of the alimentary canal, the duodenum and jejunum, are the centres around which peristaltic movements take place; but all parts, providing they be in a proper medium, are capable of undergoing rhythmical contraction.
2. These rhythmical contractions are spontaneous, and persist for a considerable time, and are capable of being modified by various stimuli.
3. The muscular coating of the stomach of Frogs, according to Ranvier, consists of only a circular layer of fibres; these are the active agent in causing contractions, and not the muscularis mucosæ.

I propose now to relate my own observations, comparing them with those of Ranvier, and then to give an account of the action of various drugs on the musculature of the Frog's stomach.

1. *Structure of the Stomach.*—It is unnecessary to go into detail here, my remarks being chiefly confined to the musculature. From without inwards we have the following layers:—

- (a) Muscular layers composed of *external longitudinal* and *internal circular* layers.
- (b) Sub-mucous or connective tissue layer.
- (c) Mucous membrane with *muscularis mucosæ*.

With regard to the layer (a), there is certainly a longitudinal layer of smooth muscle covering the circular fibres, but by no means of the same thickness. It is present in all the sections I have cut; it is thin at the cardiac extremity, but gradually increases as it gets towards, and is thickest at, the pylorus. The circular layer appears of about equal thicknesses at the two extremities of the stomach, and is thickest in the middle, the proportion between the two layers (longitudinal to circular) being at the cardia as 1:5, at the middle as 1:8, and at the pylorus as 2:5 respectively. Between these two layers the plexus of Auerbach is placed, and hence reagents will have to soak through the longitudinal layer before they can have any influence on the ganglia. Ranvier, who says there is only a circular layer, necessarily places this plexus simply beneath the peritoneal covering; hence he gave this as a reason why the stomach should be so irritable. It remains, however, to be proved whether this nerve plexus has any effect on the rhythmical contractions. Certainly, the experiments of Engelmann on the ureter, and various observers on the heart-apex of the Frog, throw doubt on its function. What the primary cause is of the rhythm in the stomach or the heart, is yet undecided. In the case of the heart-apex, one of the main factors is the pressure exerted by the circulating fluid. By increasing the pressure in a heart-apex or heart preparation which had stopped beating, the contractions can be caused to recommence. This is not borne out in the stomach, however; for, although it can well be compared with the heart, it will contract equally as well when the pressure is as great inside as out; in fact, all the results recorded here were got by simply allowing the stomach to soak in the fluid, the pressure on the inside and outside thus being equal.

What, then, will the effect of these antagonistic layers on the

lever be? If we add the ratios of each part of the stomach together, we shall have roughly the following:—Circular:longitudinal::18:4, or as $4\frac{1}{2}$:1. The circular layer thus greatly preponderates, so that we may leave the longitudinal out in our calculations. As to the effect of the muscularis mucosæ, I may add that since each layer is about equal in thickness it will be *nil*; so that the essential element in contraction is the circular layer, and this is borne out by the manner in which the stomach reacts to drugs, and by a comparison with striated muscle.

Method of Experiment.—The experiments were done with an apparatus resembling Wild's¹ modification of Brunton and Cash's² (see fig. 1). This consists of a glass cylinder (B), made by removing the bottom of a 2-ounce phial, and closing the mouth with a cork. The latter was perforated by a thin copper wire, the upper end being bent on itself into the form of a hook, which was pushed through the pyloric extremity, and then pressed tight so as to clamp this end perfectly. Another long thin copper wire was passed through the cardiac end, and simi-

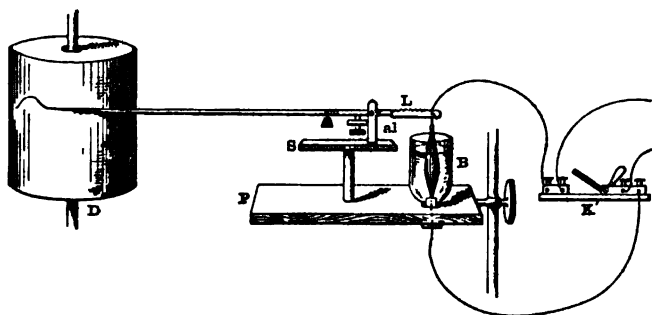


FIG. 1.—Apparatus used. For the skeletal muscle the excised stomach of the Frog was substituted.

larly clamped tight, its upper end being screwed to the short end of the lever (L). By this means a current of electricity could be sent through the preparation. The cork was then fitted to the neck, and the whole inverted, the neck of the bottle passing through a hole in the platform (P), and the phial then filled with Ringer's fluid. The long arm of the lever was composed of straw, measuring 25 inches, the short arm being

¹ *British Medical Journal*, September 13, 1887.

² *Phil. Trans.*, 1834.

1½ inch. By means of a counterpoise (*al*) on the latter, the work of the stomach could be reduced to a minimum, and the end of the lever was furnished with a small piece of stiff paper cut to a point, thus acting as a writing style on a blackened drum (D). This drum, owing to the slowness with which the stomach contracts, was driven by the axle-rod of Hawksley's recording apparatus placed on its side, and thus I was able to get a speed of $\frac{7}{8}$ inch, or just over 2 centimetres per five minutes. The platform was fitted to a brass upright, along which it was able to move, and capable of being fixed at any height by means of a screw. This upright was fitted into a stand, and by means of a tangent screw it could be rotated through one-sixth of a circle. By this means the lever point could be made to write with the smallest possible amount of friction.

With this apparatus the first few experiments were performed; but in pipetting off the solutions, when they required changing, the air caused the stomach to contract very irregularly, and it was necessary to obviate this effect. This was accomplished by placing a funnel, held in a retort-holder, above the cylinder, its lower end being connected by means of a caoutchouc joint, with a glass tube which dipped in the fluid contained in the cylinder. This caoutchouc joint was clamped, and the funnel filled with a solution of the required reagent. The cork closing the neck of the bottle was also perforated by a hole, through which passed a glass tube, having its lower end closed by a clamped caoutchouc tube. By this means the apparatus could be emptied and refilled in about five seconds, and this made the effect of the air inappreciable. With it I obtained fairly good contractions; it is an easy and quick method of getting results, and one subjecting the stomach to very little irritation.

In *preparing the stomach for experiment* the abdomen of the Frog (*Rana temporaria*) was opened, in all cases, under normal saline. The only period in which the stomach was exposed to air was during the fitting of the cork into the neck of the bottle, the hooked wire and clamped glass tube being fitted into the cork before the stomach was touched. It is necessary, in separating the stomach, to take sufficient of the duodenum and œsophagus to give room for the forceps to rest, great care being taken not to injure the walls of the stomach;

the hooks, holding it in position, of course are placed only in stomach structure.

Washing out the Contents of the Stomach.—Ranvier lays stress on this. It is, however, not always possible or necessary, because in some cases, when the stomach contained particles of food, I got as good results as when it was washed out; still, on the whole, it is the better plan. In doing so it is well not to use too much force, or it may be spoiled through over-distension.

Normal Tracing (Pl. XIII. fig. 1).—The normal tracing here described is that which I obtained with Ringer's fluid, because this solution was used in all the experiments, being better than either blood or normal saline, which will be described later.

This tracing consists of spontaneous contractions indicated by the rise and fall of the lever. At first, while the stomach is in an irritable condition, due to the manipulation consequent on putting it up, the contractions were small and irregular; after some time they became larger and more regular, and finally the stomach passed into a condition where the contractions became longer, weaker, and less rapid. They are essentially like those of striated muscle, differing only in the greater length of the latent period, slower ascent and descent, with longer elastic vibration. In addition there is always a primary continuous fall of the lever, lasting from five to ten minutes, which I can only ascribe to the irritation consequent on putting up. It cannot be due to the contraction of the longitudinal layer, for this would cause a rise, but is most probably due to the spasmodic overaction of the circular layer, because it disappears in a short time, and then the lever describes an almost horizontal line. The rise or fall is caused by the elongation or contraction respectively of the circular layer, as will be evident from what has been said above about the structure of the stomach and the kind of lever used.

The Frogs also vary somewhat. I found the contractions better in strong adult male and breeding female Frogs. During the month of August and September the contractions obtained were very small and feeble.

Normal Saline.—This was tried at first. The results with this are very variable, sometimes no spontaneous contractions being present. When they are, they present the same

general characters as with Ringer's solution, but are not so strong; they are irregular in rhythm, and only persist for about an hour at the longest.

Diluted Blood (fig. 2).—This is better than normal saline, but on the whole not so good as Ringer; only in one experiment did I get a better contraction than in Ringer. The solution is by no means so convenient to work with; it is made by adding two parts normal saline to one part blood, and requires to be fresh when used.

Mechanical Stimuli.—On pinching the stomach *in situ*, a circular constriction opposite the point stimulated was produced, and also a small one longitudinally. The former is due to the action of the circular, the latter to the longitudinal layer of muscles. Ranvier, who got the same results, assigns no reason for the latter reaction, since he says only circular fibres are present. The muscularis mucosæ can take no part in the reaction, for its layers, longitudinal and circular, are of equal thickness, and so thin as compared with the external muscular coat. Of the different parts of the stomach, the pyloric region is that which produces the largest contractions, though all parts contract.

Thermal Stimuli.—With the abdomen opened and the intestines *in situ* and in normal saline, large movements took place at a moderately quick rate at the temperature of 16°·5 C. The whole of the movements appeared to be situated round the duodenum as a centre, the whole of the remaining portion of the alimentary canal being as it were moved round this centre. They were kept up for upwards of six to eight hours. A temperature of 20° C. increased their rapidity, but above this they diminished in frequency, and stopped at a temperature above 26° C.

When put in the apparatus with lever, &c., the rhythmical contractions increase in frequency and size up to 18° C. This is, however, variable, some stomachs contracting best at 20° C. A temperature of 28° C. abolishes them, the stomach being in a state of contraction (rigor). Ranvier says the high temperature limit is 32° C.; otherwise his results are similar to

the above. The contraction at 28° C. appears to be a true "heat-rigor," and differs from the so-called "cold-rigor," in not being able to recommence contracting upon the temperature being reduced.

In all the following experiments the stomach was allowed to contract about fifteen to twenty minutes in Ringer's fluid, so as to get a normal tracing, the current was then sent through or the drug added, so that the comparison between the two might be more correct, as differences in the normal tracing, in one way or the other, sometimes took place. At times the reagent was only added when the stomach had stopped contracting, in order to see the result.

Faradaic Stimuli.—With a weak current the contractions are increased in force and the frequency diminished, but the rhythm remains regular; a current of medium intensity caused a slight rise of the lever, which remains so; while one of maximum strength sent the stomach into a state resembling tetanus, the wave-like contractions being abolished. Thus the effect produced simply depends on the strength of current used.

Galvanic Stimuli.—With one Daniell's cell (fig. 26) the spontaneous contractions were made stronger, slightly slowed, and the rhythm more regular, the form of the curve being broader at the apex. The contractions continued regularly for many hours, and with but slightly diminished vigour, the results seeming to be rather of a tonic character. There was no essential difference whether the current was an ascending (from the pylorus to the cardiac end) one or descending, or whether a make or break. The effect of the current seems to last a long time after its withdrawal. In addition it has the power of initiating spontaneous contraction (fig. 5). A slight but continuous relaxation of the stomach is caused just like the action of dilute acids on striated muscle. With three Daniell cells the contractions were still present, no difference being noticeable between this and the tracing obtained with a weaker current (one cell). This differs from the effect of a constant current on the heart, which was shown by V. Ziemssen to double the number

of beats when a strong current was passed through it and by Ludwig and Hoffa, to bring about a condition resembling tetanus, when a very strong current was used.

Chemical Stimuli—Lactic Acid.—With a solution of $\frac{1}{10000}$ (fig. 3), the spontaneous contractions were not altered in force, but were more frequent and rhythmical; they soon disappear, becoming very small in about five minutes, and almost imperceptible in fifteen. The lever rises slightly at first, showing relaxation of the stomach (circular layer), and then gradually falls (contracture), thus differing from the effect in stronger solutions, in which it agrees with the experiments of Ringer on the heart-apex, who found that acids with muscarin and pilocarpin cause a state of relaxation of the heart, while alkalies with veratria and digitalin cause a state of contraction. The above results were obtained in the winter season, at the latter end of January and beginning of February. In October, when the weather was not so cold, a solution of the same strength had less paralytic effect, the spontaneous contractions only being reduced to small rhythmic ones in fifteen minutes, and on adding Ringer's solution, the contractions became stronger, and persisted for half an hour; otherwise the effect on the lever and stomach was the same.

With solutions of $\frac{1}{3000}$ (fig. 4) the spontaneous contractions were stopped immediately; the stomach was suddenly but slightly relaxed, but afterwards passed into a state of gradual but sustained relaxation. When in this condition, a solution of $\frac{1}{1000}$ caused the relaxation to become more rapid, and next day the stomach was in a soft relaxed condition. A solution of $\frac{1}{1000}$ (fig. 6) accentuated the above features.

In all the above, while under the action of the reagent, the stomach becomes bent on itself, and thrown into circular folds, which begin at the pyloric end and go upwards.

Thus lactic acid is a strong poison to smooth muscle, even in dilute solutions, the rapidity of its action varying as the strength of solution. It causes a relaxation of the muscle, and agrees in these points with its action on striated muscle, the heart, and the smooth muscle of blood-vessels. The stimulating effect,

which the weakest solution, $10\frac{1}{1000}$, has, is in accord with a theory recently set forth, that all drugs, in a certain strength of solution, have a stimulating action, although they are ordinarily classed as strong muscle poisons.

Sodium Hydrate.—Solutions of $24\frac{1}{1000}$ (fig. 7) made the spontaneous contractions stronger, more frequent, and more regular in rhythm. The form of a single curve is as follows:—It commences with a sudden rise, which becomes slower as it reaches the summit of the curve, which is more pointed; then the descent begins, suddenly at first, but more slowly as it approaches the base line. As the action of the drug continues the contractions become weaker, the top more rounded, and the latent period longer; the contractions persist for hours, with gradually increasing contracture of stomach, which is, the following morning, in a strongly contracted and hard condition.

In strengths of $18\frac{1}{1000}$ the same reaction takes place, but the spontaneous contractions are much smaller. In certain stomachs which did not contract, spontaneous contractions were produced, small at first, becoming larger and flat-topped, but finally weak again.

With a strength of $12\frac{1}{1000}$ (fig. 8) the spontaneous contractions are abolished; in some cases at once, in others after about five minutes' action.

A solution of lactic acid, $10\frac{1}{1000}$, was added to a stomach which had been half an hour in sodium hydrate $12\frac{1}{1000}$; it causes a sharp rise, at once distinct from the sodium hydrate tracing. This rise presented a few contractions, which soon disappeared, and then the tracing became horizontal. After fifteen minutes the solution was changed to sodic hydrate ($12\frac{1}{1000}$), and then the normal action of this substance was brought into play, a moderately quick—but not so quick as that of the lactic—fall of the lever taking place, which became continuous. Thus the effect of sodium hydrate, $12\frac{1}{1000}$, is antagonistic to that of the lactic acid, $10\frac{1}{1000}$, and they both prevent the spontaneous contractions taking place.

Briefly, sodic hydrate in weak solutions acts as a stimulant, but in strong solutions it paralyses, the stomach after a long

period being in a state of rigor mortis. Lactic acid also in weak solutions stimulates, but quickly—indeed, very quickly—paralyses. In strong solutions it paralyses at once, and in all the stomach is in a relaxed condition.

The above results are essentially the same as those of Ringer on the heart-apex, with the exception that, using levers of similar orders, he got a fall with lactic when I got a rise, and the reverse with sodium hydrate. This, however, is only apparently so, for in reality, when we consider that it is the circular fibres of the stomach which cause the lever to move, and that both ends of the stomach are clamped and its cavity filled with fluid, we shall see that a contraction of the stomach will not cause a rise of the lever, but a fall, and relaxation of the stomach the reverse. This is, in fact, one proof of the circular layer being the active agent in these experiments.

Sodium Nitrite.—With a strength of $\frac{1}{10000}$ (fig. 9), the spontaneous contractions increase materially in force but not in frequency, and their form was altered. The ascent was quick, the top pointed, the descent showing at first a sudden fall, becoming less rapid near the base, and the latent period gradually becomes longer. The after effect of Ringer's solution makes the top broader. The spontaneous contractions disappear less quickly than with sodium hydrate or lactic acid. The stomach is gradually but continuously contracted. Strengths of $\frac{1}{1000}$ caused the top of the wave to become rounder, but paralysis takes place gradually from the first, the spontaneous contractions being almost gone in eighty minutes. On the addition of Ringer's solution (fig. 13) they reappear, are well marked, but weaker.

Potassium Nitrite.—With solutions containing $\frac{1}{30000}$ the contractions are increased in force, the frequency is unaltered, and the rhythm is irregular. On changing to Ringer's fluid, they are made larger and more regular, but there is no definite form of contraction-wave. The stomach undergoes gradual but very slight contraction.

A strength of $\frac{1}{10000}$ stops the spontaneous contractions in ten minutes. They recommence on adding Ringer's fluid, at first being irregular both in force and rhythm, but afterwards regular

but weak, and they persist a long time. Hence it would appear that $\frac{1}{30000}$ acts as a stimulant to, while $\frac{1}{10000}$ poisons smooth muscle. All cause a slight amount of contracture.

Quinine Sulphate.—In solutions of $\frac{1}{1000}$ (fig. 14) quinine acts best; weaker solutions have little if any definite action; stronger solutions or prolonged action of $\frac{1}{1000}$ causes the spontaneous contractions to disappear, and the stomach to pass into a state of rigor. With $\frac{1}{1000}$ (fig. 15) the spontaneous contractions are initiated when absent. If present they are increased in force, lessened in frequency, and increased in rhythm. After a time they diminish and gradually become obliterated. The rise of the lever in fig. 15 does not occur normally, but the reverse generally takes place, viz., contracture or fall of lever.

Wild¹ got the same state of contracture on the involuntary muscle of the oesophagus of the Frog. He comes to the conclusion, from experiments on striated and non-striated muscle (in the vessels, heart, and oesophagus), that quinine acts essentially the same on all forms, stimulating in small doses, paralysing in large or continued action of small, and causing a state of rigor mortis after the action of very large or prolonged action of large doses. The results are very similar to those on the stomach.

Quinine is said not to excite uterine contractions, but to stimulate them when present, and to cause tonic contractions of the uterus. Some of the experiments on the stomach would lead one to suppose that it will initiate spontaneous contractions.

Strychnine Sulphate.—Solutions containing $\frac{1}{72000}$ and $\frac{1}{30000}$ gave no definite result as to the spontaneous contractions. The effect on the lever (rise or fall) was also *nil*. With $\frac{1}{30000}$ (fig. 16) the spontaneous contractions were stopped in thirty minutes. Their force is slightly increased. The stomach is also very slightly contracted at the end of the experiment. With $\frac{1}{13000}$ the spontaneous contractions were quickly arrested, and the stomach rapidly passes into a state of contracture, which was stopped by adding Ringer's solution.

Strychnine sulphate thus acts as a stimulant in weak solu-

¹ *Brit. Med. Jour.*, September 3, 1887.

tions at first, but quickly poisons. In stronger solutions this stimulant effect is absent.

Pilocarpin Hydrochlorate.—Solutions of $\frac{1}{10000}$ (fig. 17) caused the spontaneous contractions to be slightly increased in strength, though they continue for a long time, i.e., there is little poisoning effect. The rhythm is regular, and it is able to initiate spontaneous contractions. The form is characteristic; the ascent is moderately quick, the summit round, and the descent slower than the ascent. In strengths of $\frac{1}{5000}$ the contraction form was well shown, though weaker. The addition of Ringer's solution brings out this difference better. With $\frac{1}{1000}$ (fig. 18) the form of the spontaneous contractions was best marked, the ascent being moderately quick, and the descent slower; the form is altered on adding Ringer's fluid, but returns again on adding pilocarpin. Even in this strength the poisoning effect is very little, and the stomach undergoes slow but gradual contracture. In striated muscle it causes fibrillar contractions, by irritating the motor nerve endings (Brunton).

Atropine Sulphate.—In solutions of $\frac{1}{10000}$ (fig. 24) the spontaneous contractions were lessened in force, the frequency not altered, but the rhythm made more regular. There was no definite form of contraction-wave, but it had on it a number of irregularities. There was very little paralysis, the spontaneous contraction going on after two hours; neither was the stomach in a state of contracture or relaxation.

Solutions of $\frac{1}{5000}$ had the same general effects as the above. Thus this does not agree with the researches of Szpilmann and Luchsinger, who say that atropine acts as a specific poison for smooth muscle. They found that after the action of atropine stimulation of the peripheral end of the vagus will cause contraction of the striped muscle in the œsophagus, but not of the smooth variety, although both forms of muscular tissue respond to direct stimulation. W. Stirling points out that this is doubtful, because there are no end plates in smooth muscle, so that the link between the nerve fibrils and the contractile substance is probably different in the two cases.

Veratrin Sulphate.—Solutions of $\frac{1}{30000}$ made the spontaneous contractions stronger, more frequent, and rhythmical. The stomach undergoes at first a dilatation, then a very gradual contracture. With strengths of $\frac{1}{10000}$ the spontaneous contractions were just like a monocrotic pulse-wave (fig. 25); they remained so for about twelve contractions, and then began gradually to show a wave like that of the radial artery, and they are present for some time. The stomach in this and the rest was similar to the above in a state of contracture.

Strengths of $\frac{1}{3000}$ (fig. 11) caused the monocrotic waves to be well developed, and on adding Ringer's solution for a short time the pulse-like tracing reappeared. In this case they were accentuated by again adding veratria. With $\frac{1}{1000}$ the spontaneous contractions stopped, but reappeared in an accentuated form on adding Ringer.

Digitalin (fig. 20).—With a solution of $\frac{1}{30000}$ the spontaneous contractions were increased in strength, lessened in frequency, and the rhythm remained regular. The contractions are not unlike those of a radial pulse tracing, with gradually decreasing tension. The stomach also undergoes slight contracture.

Ringer has pointed out that veratrin and digitalin agree with alkalies in causing the muscle of the heart to pass into a state of contracture, while acids, with muscarin and pilocarpin, cause relaxation. It will be seen that with veratrin and digitalin a similar action takes place with the non-striated muscle of the stomach; whether it is due to their action on the nervous or muscular tissue remains to be proved. According to most observers, in the heart at least it is said to act on muscle. On the stomach, however, muscarin and pilocarpin cause contraction, not dilatation.

Muscarin Nitrate.—With strengths of $\frac{1}{10000}$ (fig. 21) the spontaneous contractions are increased in force and unaltered in frequency and rhythm, which last remains good. The form is also altered—a sudden ascent, then a pointed apex; then the descent, at first sudden, but becoming slower, and drawn out as it approaches the base (fig. 22). It is very characteristic. With renewed

Ringer's solution the contractions become irregular again; similar to those before the muscarin was added. On now adding muscarin, in about five minutes a tracing similar to the above is obtained. The contractions, however, gradually become weaker, but retain their form to the end.

The stomach is gradually contracted, but very gradually. This thus differs from the relaxed condition of the heart under the action of the same drug.

With $\frac{1}{8000}$ the above was accentuated.

With $\frac{1}{4000}$ (fig. 23) the first four spontaneous contractions were staircase in character, then they resumed their characteristic form.

With $\frac{1}{2000}$ the first twelve spontaneous contractions were also staircase in character, but of much greater height. The rest of the tracing was similar to the above, but the hardness and contracture on the following day were greater than the others.

Thus, even in strong solution, muscarin has little paralytic effect. In this respect it is similar to veratrin, and both are able to initiate rhythmical contractions, and cause a condition of rigor mortis. Of all the muscle stimulants, muscarin nitrate appears to be the best (on the stomach, however). On the heart, muscarin is said to stimulate the inhibitory ganglia. May not the great effect on the stomach be due to stimulating the plexus of Auerbach and muscle fibres as well?

Experiments on the antagonistic Action of some of the above Drugs—Atropin Sulphate and Muscarin Nitrate (fig. 19).—When muscarin, $\frac{1}{10000}$, was added to atropin, $\frac{1}{10000}$, the irregular form of contractions got by the latter was altered to moderately regular but slightly larger ones. None of the characteristic contractions of muscarin were produced. On adding muscarin, $\frac{1}{2000}$ (fig. 10), to a stomach which had been acted on by atropin, $\frac{1}{3000}$, the contractions peculiar to muscarin were produced; they were obliterated by atropin, $\frac{1}{3000}$, again. Thus muscarin can abolish the spontaneous contractions produced by atropin, and *vice versa*, while veratrin has no effect on the atropin curves. This result agrees with the experiments on the heart, atropin paralysing the inhibitory

branches of the vagus, while muscarin stimulates them, each being capable of removing the effect of the other.

Veratrine Sulphate and Strychnine Sulphate.—Veratrine, $\frac{1}{5000}$, caused a rise of the lever, and the stomach went into a state of tetanic contractions. On adding strychnine, $\frac{1}{5000}$, the lever began to fall, and spontaneous contractions commenced.

Atropin Sulphate and Pilocarpin Hydrochlorate.—Atropin, $\frac{1}{5000}$ (fig. 12), instantly abolishes the rhythmical contractions caused by pilocarpin, but they are again reproduced in a weaker form by pilocarpin, $\frac{1}{5000}$, after about twenty minutes' action.

In the above experiments, in no case is the result derived from one trial, many of them being repeated many times. Owing, however, to the slowness of contraction and constant attention which is necessary, much time and labour must be expended. In some of the Frogs also there appears to be a certain amount of idiosyncrasy, as in the quinine experiment, from which fig. 15 is taken. In this stomach, as noted in the text, relaxation instead of contracture occurred.

The above experiments were carried out in the Physiological Laboratory of the Owens College, under the direction and supervision of Professor Stirling, to whom I tender my sincere thanks for the kind assistance he has rendered me in many different ways.

EXPLANATION OF PLATE XIII

In all figures, R = Ringer's solution. Vertical line = time of changing solution. $\frac{1}{10000}$, &c. = 1 part of drug in 10,000 parts of Ringer's solution. Drum revolves at rate of $\frac{7}{8}$ inch per 5 minutes. Tracings should be read from left to right →.

Fig. 1. Normal tracing from near the beginning of original tracing showing part of initial fall of lever.

- Figs. 5 and 26. G = galvanic current.
 „ 7 and 8. NaOH = caustic soda.
 „ 9 and 13. NaNO₂ = sodium nitrite.
 „ 10, &c. Atrop. = atropin sulphate.
 „ 11, &c. Verat. = veratrin sulphate.
 „ 12, &c. Piloc. = pilocarpin hydrochlorate.
 „ 14, &c. Q. = quinine sulphate.
 „ 16. Strych. = strychnine sulphate.
 „ 21, &c. Musc. = muscarine nitrate.

The remaining figures sufficiently explain themselves.

ADDITIONAL NOTE ON THE INFLUENCE OF POSTURE ON THE FORM OF THE ARTICULAR SURFACES OF THE TIBIA AND ASTRAGALUS IN THE DIFFERENT RACES OF MAN AND THE HIGHER APES. By ARTHUR THOMSON, M.A., M.B.,
Lecturer on Human Anatomy in the University of Oxford.

As a supplement to my former paper¹ I now forward some additional observations, the material for which has been kindly placed at my disposal by Professor Sir Wm. Turner. Thirty-seven skeletons in the Anatomical Museum of the University of Edinburgh have been examined. The results have been tabulated, and arranged in accordance with the plan adopted in my former communication. Most of these skeletons have been described by Professor Turner in connection with other features in their anatomy in his "Report on Human Skeletons" in *Challenger Reports*, part xlvii., 1886.

I need not recapitulate what has been already stated. The results obtained correspond in a very marked manner with the conclusions already arrived at. The Australian series includes eight specimens; in these the curvature of the external condyloid surface averages 2.1, as compared with the mean of 2.5 for fourteen skeletons given in my previous table. In the eight Edinburgh skeletons, the inferior facet on the tibia occurs eight times, the facet on the astragalus seven times (the astragali in one instance are wanting), as compared with the numbers 11 and 7 respectively in the previous series. Now, as then, in no instance is there an absence of these facets. Similarly, in the Andaman skeletons we have a close correspondence. The Edinburgh collection contains five specimens, the average curvature of the external condyloid surface of which is 2.7, as compared with 2.7 of the previous series. Articular facets are present on the tibiæ in two instances, doubtful in one, and absent in one. On the astragalus the facet occurs in four cases; in one bone there is no facet.

¹ *Jour. Anat. and Phys.*, vol. xxiii. p. 616, July 1889.

The corresponding figures in the former table, wherein the average of twenty-five skeletons is given, is that the facet on the tibia occurs well marked in eighteen instances; in five its presence is doubtful. So also in the case of the astragalus; the figures are, twelve well marked, seven doubtful. The only other group to which I need refer is the Negro specimens. Of these there are five in the Edinburgh collection. Unfortunately we have little or no information as regards the locality from which they were obtained, and it appears not improbable that some at least of them were slaves. Under these conditions, it is not surprising that the specimens examined display consider-

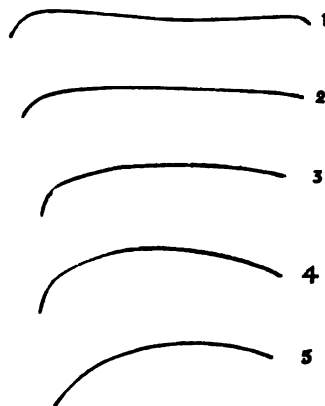


FIG. 1.—Varieties in Contour of external Condylar articular surface of Tibia.

able diversity. In my former paper I referred to the unusual flatness of the external condyloid surface, the average of which in seven cases was 1.3. In the five specimens here tabulated the average is as high as 3. On the other hand, in the five Edinburgh skeletons the tibial facet is *absent* in three instances, and well marked only in one case. In this connection I am indebted to Dr St John Brooks for the following interesting observation. He writes, in regard to the Zulus, among whom he lived for fourteen years, "The squatting position is never assumed by the females; even the smallest girls habitually sit in the position No. 1 in the photograph I enclose." (The position here referred to is one in which the girl is represented as resting the buttocks and right thigh on the ground, with the

knees flexed and the legs directed towards the left side.) "The *males*, on the contrary, squat down, and the practice prevails to

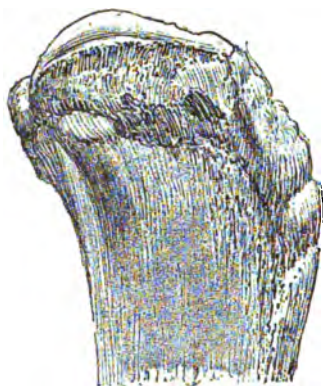


FIG. 2.—Upper end of Tibia of a male Andaman Islander, showing convexity of external condylar articular surface.

such an extent that in men over thirty-five or forty the skin just below the patella has usually a baggy appearance." We have here a possible explanation of the absence of these facets in the two Negresses examined, for in all likelihood this practice is not confined to the Zulus. It will, therefore, become a matter of importance in future to determine, if possible, the sex of the skeleton.

As the tables are similar in their arrangement to those already published, comparisons can readily be made between the individual specimens and the averages of

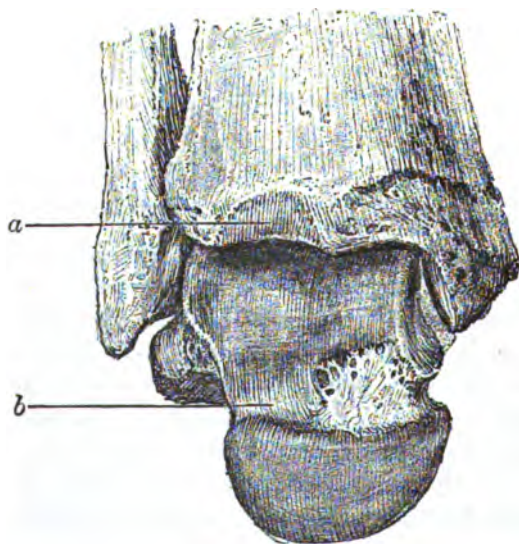


FIG. 3.—Tibia and Astragalus of a Veddah. *a*, tibial facet ; *b*, facet on astragalus.

the series, so that it is not necessary further to enlarge upon this subject.

In the discussion which ensued when my former communication was read before the Anatomical Society of Great Britain and Ireland, Mr Shattock referred to a paper, "On the Pathology and Etiology of Congenital Club-Foot,"¹ of which he was joint author with Mr Parker. Since then I have had an opportunity of reading the memoir. He draws attention to the fact that in the cases of talipes equinus examined by him he found a facet extending along the *inner* side of the upper surface of the neck of the foetal astragali. In referring to the Apes he

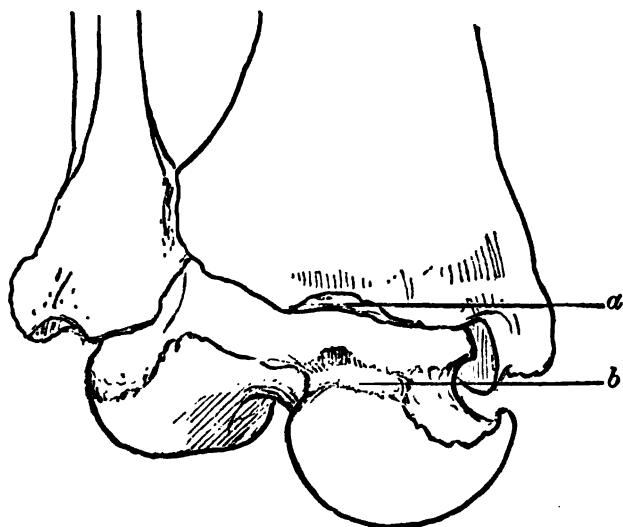


FIG. 4.—Tibia and Astragalus of a Gorilla. *a*, facet on tibia; *b*, facet on astragalus, it takes in this specimen the form of a tubercular ridge, the upper surface of which is smooth.

mentions the fact that a similar arrangement of articular surfaces is to be seen on the neck of their astragali, a condition which, he states, remains in these creatures as the normal arrangement in the adult. In respect to this, my own observations do not bear out Mr Shattock's conclusions; in his foetal astragali, he states that the facet is situated on the inner side of the neck, and in extreme flexion of the ankle comes in contact with the internal malleolus. In the adult specimens of astragali examined by me I have found the articular surface along the *outer* side of the upper surface of the neck of the

¹ *Trans. Path. Soc. Lond.*, 1884, vol. xxxii. p. 423.

bone, and this surface articulates with a facet on the inferior margin of the tibia, *placed rather towards the fibular side*, as shown in the plate. Again, in the Anthropoids, in which I have inspected the astragali, the facet, when present, was placed *not* along the *inner border* of the neck, but along the *outer aspect*. In some cases there was an extension forward of the inner portion of the superior articular surface, but in no instance did this articulate with the facet on the anterior margin of the inferior articular surface of the tibia, a surface which, in every instance in which it was present, came in contact with the articular surface on the *outer border* of the neck of the astragalus in extreme flexion of the ankle.

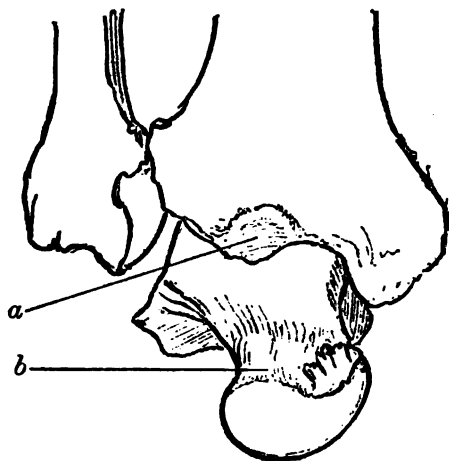


FIG. 5.—Tibia and Astragalus of an Orang. *a*, facet on tibia; *b*, facet on astragalus.

I have had an opportunity of dissecting the articulation in the Chimpanzee and Orang, thanks to the kindness of Professor Cunningham. In the former a distinct pyriform facet, coated with cartilage, was present on the upper surface of the neck of the astragalus; this surface was separated by a small non-articular area from the superior articular surface. In flexion of the foot the rounded margin of the tibia, which was coated with articular cartilage, rested in this hollow on the neck of the astragalus.

In the Orang (a young specimen), the neck of the astragalus was remarkably smooth and hollowed out, though there was no

regular layer of encrusting cartilage; as in the Chimpanzee, in extreme flexion the border of the tibia fitted into this hollow so that the joint was locked by the checking of the surfaces.

In conclusion, I may add that I recently met with a specimen in an adult male subject, in which this facet was well seen on the neck of the astragalus, there being a distinct prolongation forward of the articular cartilage from the superior articular surface. Unfortunately, I could obtain no information in regard to the habits of the individual, so that we are unable to state what may have caused the production of the facet in this instance.

TABLE I.

	Diameters of Tibia.		Index of Pharyngema.	Curvature of External Condylloid Surface of Tibia.	Inferior Tibial Facet.	Facet on Neck of Astragalus.
	Transverse.	Ant. post.				
Burke (the murderer),	22.5	37.5	60	1	—	—
Howison (the Cramond murderer),	23.5	36.5	64.3	2	—	—
Skeleton, found in sand near Prestonpans, N.B.,	24	33	72.7	1	—	
Prehistoric (found in stone cyst, Leith),	22	30	73.3	4	Facet small, well marked	Facet
Lapp ♂ (Ost Finmarken),	22	30	73.3	3	Facet small	Facet
Lapp ♀,	20	26.5	75.4	3	Facet	Facet
Hindoo ♂ (Sir Joseph Fayrer),	22.5	32.5	69.2	2	Facet *	Neck smooth along outer side, though defined from sup. artic. surface
Hindoo ♀ (Sir Joseph Fayrer),	20	27	74	3	—	—
Hindoo ♂ (Dr J. Anderson),	22.5	34.5	65.2	2	—	—
Sikh (Dr D. D. Cunningham),	23.5	39	60.2	1-2	Facet *	Tubercular ridge with smooth surface
Kanaka, A (Oahu),	16.5	27	61.1	3	Facet	Facet
Kanaka, B (Oahu),	22	32.5	67.7	3	Facet	Facet
Maori (Otago, N.Z.),	23	35	64.7	2	Facet *	Facet
				Upper end of shaft recurved		
Maori (New Zealand),	25	34	73.5	3	Facet *	
Eakimo ♀ (Monro Collection),	23	39	59	1	Slightly lip-ped, no facet	—
Eakimo ♀ (Monro Collection),	22.5	32	70.3	2	Facet	Smooth on neck
Australian (Eucla),	24	32.5	73.8	2-3	Facet small	Smooth on neck

TABLE I.—*continued.*

	Diameters of Tibia.		Index of Platyæmia.	Curvature of External Con- dyloid Surface of Tibia.	Inferior Tibial Facet.	Facet on Neck of Astragalus.
	Trans- verse.	Ant. post.				
Australian (Swan Hill, N.S.W.),	81	40	77.5	2 Upper end of shaft slightly recurved	Facet *	Facet *
" (West Victoria, Mr Dawson),	19	29	65.5	3-4	Facet **	Facet **
" (Manly Cove, Prof. T. P. A. Stewart),	24	38	63.1	1 Surface ob- lique, head recurved	Facet	Facet
" (N.S.W., Dr M. Reid),	27.5	37.5	73.3	1 Slightly re- curved	Facet	Facet *
" (Perth, W. Aus- tralia),	22.5	34	66.1	2 Slightly re- curved	Facet	
" (young person from Murray River),	20	26	76.9	Damaged, but upper extremity much re- curved.	Facet	Facet *
" (Queensland, Challenger),	23	35	65.7	2	Facet	Tubercular ridge, with smooth sur- face
Andaman ♂ No. 1,	17	27	62.9	3	—	—
" ♂ No. 2,	18	27.5	65.4	2-3	Facet	Smooth ridge
" ♀ No. 3,	17	26	65.3	Damaged	Damaged	Slight ridge smooth on surface
" ♀ No. 4,	18.5	26	71.1	2	Facet	Smooth neck and slight ridge
" ♂ No. 5,	16	29.5	54.2	3	Bevelled	Well-marked tubercular ridge smooth on surface
In the box containing the skeleton of Andaman No. 2 three are three tibiae—one, much larger than the other two, which are evidently pairs, has a distinct facet in- feriorly.						
Negro, No. 1 (Monro Col- lection),	24	35	68.5	3	Facet	Facet, tho' not contin- uous with sup. artic. surface
Negress, No. 2 (Monro Collection),	30	42.5	70.5	3-4	—	—
Negress, No. 3 (Prof. Goodsir),	22	29.5	74.5	2	Bevelled	Smooth on neck
Negro, A. (Monro Collec- tion),	25	35	71.4	2	—	—
Negro, B. (Monro Collec- tion),	29	43	67.4	4	—	—
Bushman (Dr Sutherland)	23	31.5	73	1	Facet ?	—
Bushman (Challenger),	17	23	60.7	Mutilated	Facet ?	—
Creole,	23	34	82.3	1	Facet small	Slight ridge, smooth on surface

TABLE II.

	Average Index of Platyknemia.	Maximum of Platy- knemia.	Minimum of Platy- knemia.	Average Curvature of External Condyle.	Type Series.					Facet on Inferior Margin of Tibia.	Facet on Tibia doubtful or Margin Revelled.	No Facet on Inferior Margin of Tibia.	Facet on Neck of Astragalus.	Facet on Neck of Astragalus doubtful.	No Facet on Neck of Astragalus.
					Curvature No. 1.	Curvature No. 2.	Curvature No. 3.	Curvature No. 4.	Curvature No. 5.						
EUROPE— 3 British, 2 Lepcs, 1 Prehistoric,	65.6 74.3 73.3	60 73.3 ...	72.7 75.4 ...	1.3 8 ...	2	1	2 ... ...	... 1 ...	... ... ...	1 1 2	... ... ...	3	1 1 ...	... ... ...	2
ASIA— 4 Natives of India,	67.1	60.2	74	2.2	...	3	1	...	...	2	...	2	2	...	2
POLYNESIA— 4 { 2 Kanakas, 2 Maoris,	66.7	61.1	73.5	2.7	...	1	3	...	...	4	...	...	3	...	...
AMERICA— 2 Eskimo,	64.6	59	70.3	1.5	1	1	...	...	...	1	1	...	1	...	1
AUSTRALIA— 8 Mixed Australians,	70.2	65.4	77.5	2.1	2	3	1	1	...	8	...	...	7	...	...
MELANESIA— 5 Andamans,	63.7	54.2	71.1	2.7	...	1	3	...	...	2	1	1	4	...	1
AFRICA— 5 Negroes, mixed, 2 Bushmen,	70.4 66.8	67.4 60.7	74.5 73	3 1	1 ...	2 ...	1 ...	2 ...	... ...	1 ...	1 2	3 ...	2 ...	... ...	3 2

A CASE OF HERMAPHRODITISM IN A COMMON
FROG (*Rana temporaria*). By W. RAMSAY SMITH, B.Sc.,
Senior Demonstrator of Zoology, University of Edinburgh.

IN a brief note I wish to record a case of hermaphroditism of a somewhat rare and interesting character. The animal, a full grown frog of the species *R. temporaria*, exhibits on the right side of the body very completely the male characters with some female characters in addition, and on the left side the female characters with some of the male.

On the right side the testis, 15 mm. long, is more than ordinarily developed, and presents several constrictions in place of the normal ovoid outline. The *corpus adiposum* is of large size, and is attached, not to the testis, but to the spermatic and renal vessels. Besides these male characters there are present two distinctly female features, (1) on the outer margin of the testis and in very intimate connection with it a small quantity of ovarian tissue, in which the outlines of eggs can be easily distinguished; (2) a complete oviduct of fairly large size and distinctly convoluted.

On the left side the ovary is of the normal size and appearance, and contains eggs in various stages of development. The *corpus adiposum*, which is attached to the ovary, is abnormally large and much more branched than usual. The oviduct is of normal size, and is more convoluted than the one on the right side. Both oviducts expand, as is usual in the female, into "uterine segments" posteriorly. In addition to these characters peculiar to the female, there is one male feature, the presence, on the outer margin of the ovary and in very intimate connection with it, of a nodule of spermatic tissue 3 mm. in diameter, and on the inner margin, of another nodule 2 mm. in diameter.

On both sides the ureter and oviduct show the female characters; there is no trace of a *vesicula seminalis*.

Some minor points claim attention:—the right manus has the first digit stouter than the left, with a perceptible swelling

marking the position of the cushion, a male character of which there is no trace on the left side; and the skin below the throat is lighter on the left side than on the right, this lighter colour being a fairly constant feature in female frogs at the breeding season.

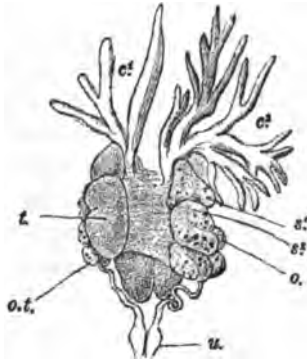
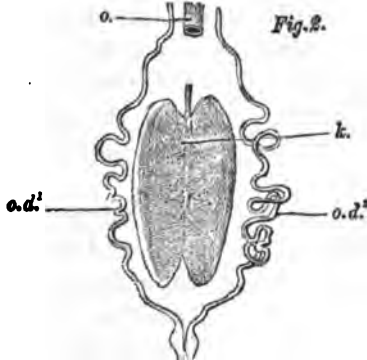
Fig. 1.*Fig. 3.**Fig. 2.**Fig. 4.*

FIG. 1.—Genital organs: ventral view. *t.*, testis; *o.t.*, patch of ovarian tissue; *c¹*, right *corpus adiposum*; *o.*, ovary; *s¹*, *s²*, nodules of spermatogenic tissue; *c²*, left *corpus adiposum*; *u.*, "uterine segment" of oviduct.

FIG. 2.—Oviducts. *o.*, oesophagus; *o.d¹*, *o.d²*, right and left oviducts; *k.*, kidneys.

FIG. 3.—Right manus: palmar surface.

FIG. 4.—Left manus: palmar surface.

[All the drawings are of the natural size.]

THE ANATOMY OF THE TRANSVERSALIS MUSCLE
AND ITS RELATION TO INGUINAL HERNIA. By
KENNETH M. DOUGLAS, M.D. & F.R.C.S. Edin.

THE following notes on the transverse muscle of the abdomen are abstracted from a more extended Thesis on the Surgical Anatomy of Inguinal Hernia, the practical work for which was done in the Anatomical Institute of Leipzig, under Professor Braune, to whose kindness and advice much is owed.

A series of thirty-four dissections was studied, twelve of these having been prepared by myself with great care; all the subjects save one were male, and herniæ existed in five cases.

If one assume the usual description in the books of the *Transversalis muscle* to be accurate, one sees that at the place where the spermatic cord traverses the abdominal wall, there is a distinct weakness over and above the presence of the inguinal canal, because only two muscular strata exist instead of three, as elsewhere. Indeed, according to this description, between Poupart's ligament and the lower edge of the transversalis muscle, only a thickened fascia transversalis and the aponeurosis of the external oblique intervene between the superficies and the peritoneum.

One would rather have expected to find this part of the wall increased in strength, and I have been led to believe that this is so, and that all the strata are present and so arranged as in a measure to compensate for the weakness necessarily brought about by the presence of the inguinal canal: the transversalis muscle forming in fact an integral part of that canal, and entering into important relations with herniæ, both direct and oblique.

Before discussing these relations, however, one may note certain points regarding this muscle, and turn the attention first to the *Fold of Douglas*.

This, the free lower margin of the posterior lamina of the rectus sheath (fig. 1, A) is of characteristic arched form, and the concavity lying downwards, the extremities or pillars of the

arch must descend. Braune, in his *Atlas of Veins* (Appendix), has indicated the attachment of these pillars to the pelvis, without however entering into any exact description.

The *inner pillar* (fig. 1, B) descends to the pubic bone, and ends in the adminiculum linæ albæ (fig. 1, B, cf. Henle, *Muskel-lehre*, fig. 32). The descending fibres of the *outer pillar* of the fold form a tendinous band (fig. 1, C) of varying breadth and strength. Braune has called this the *ligament of Hesselbach*, it having been first noted by that anatomist as a part of the *fascia transversalis*, and named *ligamentum inguinale internum* (vide *De ortu et progressu herniarum*, p. 10). In some instances it may almost escape notice, but after careful removal of the peritoneum and *fascia transversalis*, one can define it by means of a blunt-pointed instrument.

This ligament lies on a plane behind that of the main tendon of the transversalis, which at this level passes inwards as far as the rectus; yet, being continuous with the Douglas fold, it forms a part of that tendon.

Internally it presents a free concave margin, forming the outer limit of that gap in the posterior aspect of the abdominal wall, in which there lie exposed the rectus muscle (fig. 1, E) and the epigastric vessels, when one strips off the *fascia transversalis*.

Note.—This gap in the rectus sheath has been the object of much study, and many theories have been propounded to explain its presence. Retzius, after whom it has been sometimes called the *cavum præperitoneale Retzii*, believed it to be designed for the accommodation of the expanding bladder, and Gegenbaur concurs. Henle, and after him Luschka, held that it existed to relieve from pressure the epigastric vessels. I should incline to take another view of its significance, and one which, so far as I am aware, has not hitherto been advanced. One can see no very great need for the protection of the epigastric vessels from pressure; but in this same region there lay a vessel in the fœtus of vital moment. Had the *hypogastric artery* lain amid dense tendinous layers, one may imagine that their movements would impede the foetal circulation, whereas, lying as it does between

the rectus muscle (which in the intrauterine position of flexure is especially soft) and the soft abdominal contents, any such impediment is prevented.

Externally the ligament of Hesselbach is joined to the main transversalis tendon, and might thus be said to form the edge of an incomplete posterior lamina of that structure.

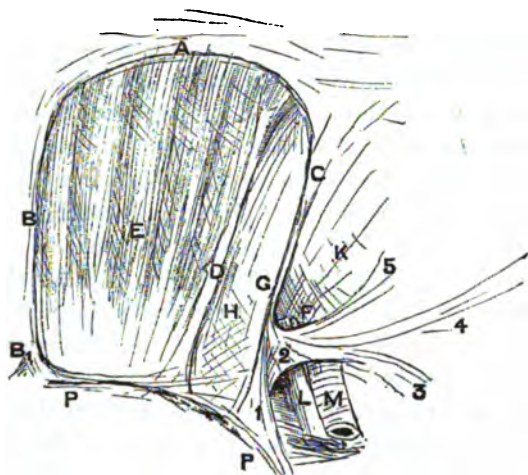


FIG. 1.—Abdominal Aspect of Transversalis Muscle (Peritoneum and Fascia Transversalis removed). A to K and 1 to 5, *vide* letterpress; L, ext. iliac vein; M, ext. iliac artery; PP, pelvic brim.

The lower end of this band (fig. 1, c_1) forms a *distinct internal pillar to the deep abdominal ring*, and then its fibres divide and pass in different directions. Some are attached to the ligaments covering the horizontal pubic ramus, and to the pectineal fascia, internal to the deep crural ring (fig. 1, 1); others pass to the margin of the deep crural arch (fig. 1, 2) and there end for the most part, though some may be traced into the falciform fascia. A large bundle of fibres passes round the deep abdominal ring, constituting its inferior and horizontal pillar, the *ligamentum inguinale laterale of Henle* (*vide* description of the Transverse Fascia), the fibres of which are traced to the psoas fascia (fig. 1, 3), to the deep surface of the superficial crural arch (fig. 1, 4), and upwards to reach the transversalis tendon outside the deep ring (fig. 1, 5).

This ring may thus be regarded as constituted by the trans-

versalis tendon, a fact of no little importance in relation to the strangulation of oblique inguinal hernia. The idea that the deep ring is constituted by muscle, has been suggested by Guthrie, Luschka, and Cooper, but not as in the above description.

Braune (*loc. cit.*, p. 69) has noted likewise a second descending limb of the outer pillar of the Douglas fold, passing from the upper end of the ligament of Hesselbach obliquely downwards and inwards to the pubic bone just external to the rectus tendon, to which it is in its whole length attached (fig. 1, D). He has named it *the ligament of Henle*; it is more easily recognised than the ligament of Hesselbach, though also varying in strength, and more notably in breadth.

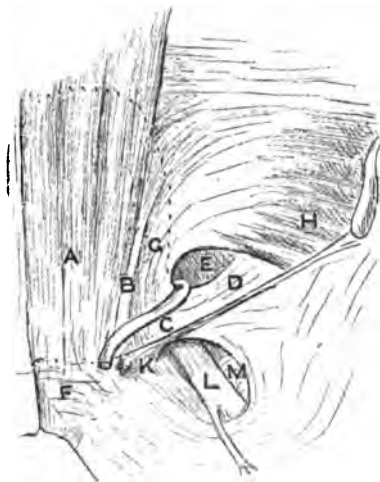


FIG. 2.—Superficial Aspect of Transversalis Muscle (Oblique Muscle removed).

One must now for a little consider the tendon of the transversalis as viewed from the superficial aspect, assuming that both oblique muscles have been wholly removed; one observes that there still remains a well-marked tendinous layer, which, seeing that removal of the transversalis fascia does not affect it, must belong to the transversalis muscle (fig. 2, G).

In the removal (or reflection) of the internal oblique, fibres are found uniting it with the subjacent transversalis, sometimes very strong and numerous, sometimes very sparse. This union

has given rise to the description of a conjoined tendon, which is commonly looked upon as largely composed of transversalis fibres. In my opinion, though that muscle usually takes part in its formation, in some instances it does not do so at all, and in all cases the more important rôle in this particular is played by the internal oblique muscle.

If these uniting fibres be divided, the transversalis muscle may be fully exposed to view; and one sees its fibres arching from their origin on the superficial crural arch (fig. 2, H) to the pubic region (fig. 2, F), where they are attached, not alone together with the internal oblique, but by the deeper tendon just alluded to.

This tendon extends inwards as far as the rectus (fig. 2, A), with which, for a little distance above the pubes, it is firmly incorporated—a fact to which great attention should be paid, as also to this second fact, that the most internal fibres of the tendon are always the strongest, and form a distinct band (fig. 2, B), passing up to and in front of the fold of Douglas (position shown by dotted line in fig. 2). This is the ligament of Henle already mentioned, and it would appear to be, not as Braune thought, continuous with the fold of Douglas, but to lie anterior to it in the wall. When the anterior lamella of the sheath of the rectus is wholly removed, this ligament and the adjoining portion of the transversalis tendon remain undisturbed. This muscle must therefore be looked upon, not as forming part of that sheath below the Douglas fold, but as joining and uniting with the edge of the rectus tendon.

Further outwards the transversalis tendon (fig. 2, C) is attached behind the pubic spine for a varying distance along the iliopectinal line, and to the pectineal fascia behind the ligament of Gimbernat (fig. 2, K), the abdominal aspect of which it frequently conceals. The most external fibres of the tendon bound the deep abdominal ring (fig. 2, E), and are strengthened by the *ligament of Hesselbach*, which lies behind them; from thence they pass (fig. 2, D) out into the deep crural arch.

The tendon of the transversalis muscle, according to the account now given, must have very direct relations to inguinal hernia.

The direct variety, indeed, leaves the abdomen between the

ligament of Henle and the ligament of Hesselbach, which both, as we have seen, pertain to the transversalis muscle; and it is of much interest to note that the peritoneum, in relation to the space between these structures, is that forming the so-called *middle* inguinal pouch.

The internal peritoneal pouch is in apposition to the ligament of Hesselbach and the tendon of the rectus, which must render it impossible for any rupture to pass through that pouch except the *unusual* "internal oblique hernia" of Velpeau, which, protruding internal to the obliterated hypogastric artery, passes downwards and outwards to gain the outer margin of the ligament of Henle, and leaves the abdomen at the same point as a rupture in the middle pouch.

There is thus practically but one variety of direct inguinal hernia, that which lies in the middle peritoneal fossa; and certain anatomists do not look upon the internal fossa as of any importance in relation to hernia. Tillaux calls it "*supra pubic*," and His the "*supra vesical fossa*," rather than inguinal. It being the broadest of the three peritoneal fossæ in most cases, one may surmise that their breadth is not a factor in the determination of the point of egress of a hernia.

It is important to note that in the area between the ligaments of Henle and Hesselbach (fig. 1, H), through which *all* direct herniæ pass, the tendon varies notably in strength. In some preparations it is strong and resistant, so that rupture at this point could not readily occur; in other instances it is thin and yielding, and one may presume the tendency to rupture to be considerable; while in some cases an actual gap in the tendon may be found, so that nothing but transversalis fascia separates the peritoneum from the interior of the inguinal canal, and great disposition to rupture is brought about.

Unless this gap be present, or the hernia has burst through the tendon, the transversalis muscle forms a covering of direct hernia intervening between fascia transversalis and cremasteric fascia.

Oblique inguinal herniæ passing through the deep ring come into contact with its internal pillar, which, as stated above, is formed by the transversalis tendon, while in their course through the canal the tendon arches over the neck of the sac, seeing that

at the deep end of the canal it forms part of the anterior wall (fig. 1, K), and at the superficial inguinal ring part of the posterior wall (fig. 2, G).

The importance of these relations with respect to the *possibility* of muscular or spasmodic strangulation may be readily appreciated.

In contending that the various tendinous structures noted in this paper are truly such, and do not pertain, as described by Henle, Cloquet, and other anatomists, to a thickened fascia transversalis, one is not indulging in mere anatomical *finesse*. The difference, as regards the causation and the strangulation of herniæ, must be an important one, whether namely, they are mere fascial bands, or tendon fibres influenced directly by muscular action.

Among the many works I have had occasion to consult, great discrepancies and varying descriptions of the same structures exist, but some authorities, in greater measure or less, give an account similar to the foregoing, viz., A. Velpeau, *Anatomy of Regions*, Introd., p. 64; Cruveilhier, *Anat. Descriptive*, p. 50; Astley Cooper, in his work on *The Structure of the Testis*; Scarpa, in his *Traité Pratique des Hernies*, p. 25; and Sappey, in his *Traité d'Anatomie Descriptive*, vol. ii. p. 232. Winslow and others have noted the independent pubic attachment of the transversalis.

ON THE SPIRACLES OF THE PORBEAGLE SHARK
(*LAMNA CORNUBICA*). By J. C. EWART, M.D.,
*Regius Professor of Natural History, University of
Edinburgh.*

IN 1875 Professor Turner, in a paper "On the Presence of Spiracles in the Porbeagle Shark (*Lamna cornubica*),¹ pointed out that "zoological writers differ in their statements as to the spiracles in the Porbeagle." And notwithstanding the fact that Turner found distinct, though small spiracles in a specimen,² measuring 3 feet 5½ inches in length, there seems to be still some doubt on the subject. In 1884 Day,³ after the statement "small spiracles placed midway between the eye and the first gill-opening have been observed" (Turner), adds, "Günther has found them absent." As mentioned by Professor Turner, spiracles were said to be absent by Fleming and Parnell, and present by Müller, Henle, and Duméril. Dr Günther,⁴ while stating that he found a minute pore-like foramen on one side, of *Lamna spallanzani*, says spiracles are absent in the Porbeagle.

From this diversity of opinion it might be inferred that minute spiracles are present in some specimens of *Lamna cornubica*, but absent in others. I am, however, inclined to believe that they are always present, at least I have invariably found them in specimens varying in length from 11 inches to about 8 feet. In the smallest specimen⁵ examined I had great difficulty in finding the spiracles, and for a time believed they were absent. Eventually, however, I discovered a minute

¹ *Jour. Anat. and Phys.*, vol. ix., 1875.

² A portion of skin, showing one of the spiracles in the Porbeagle referred to by Professor Turner, is preserved in the Anatomical Museum of the University of Edinburgh.

³ *The Fishes of Great Britain and Ireland*, p. 298.

⁴ *Catalogue of British Fishes*, vol. viii., 1870.

⁵ This specimen, which only measured 11 inches in length, was taken from the oviduct of a large Porbeagle by Mr Sim of Aberdeen.

foramen on the right side, about 7 mm. behind the eye, into which I was able to introduce a fine horse hair. The foramen led into a short, delicate canal of about $2\frac{1}{2}$ mm. in length, which opened into a well-marked elongated hyomandibular pouch lying parallel with the hyobranchial or first gill cleft. With the most careful scrutiny I was unable to detect the external aperture of the left spiracle. But on examining the left hyomandibular pouch, I observed a small pit on its outer aspect, into which I introduced a fine horse hair. Without any difficulty, this hair, after passing through a short canal, emerged from the hitherto unseen pore on the surface; this pore corresponded exactly in position with the slightly larger aperture on the opposite side. In a Porbeagle measuring 3 feet 6 inches in length, the apertures were quite distinct. They were nearly oval in form, measuring $1\frac{1}{2}$ mm. from before backwards, and about 1 mm. from side to side.

In the head of a Porbeagle (in the possession of Dr Traquair, F.R.S., of the Edinburgh Science and Art Museum), from a specimen which probably measured 8 feet in length, both spiracles were quite distinct and as nearly as possible of the same size. They measured 3 mm. by about 2 mm. It thus appears that the spiracles, extremely minute in the embryo, slightly increase in size as the Porbeagle increases in length. The fact that they are present in large specimens seems to me to favour the view that if not invariably present they are more constant than might be supposed from the observations hitherto recorded. Although I have always found the spiracles, I have been unable to detect any vestige of a pseudo-branchus.

In conclusion, I may say that, from an examination of the spiracles in *Lamna*, *Galeus*, *Læmargus*, *Acanthias*, and *Scyllium*, I have been unable to obtain any evidence in favour of Professor Cleland's statements¹ that "the spiracle is preoral in front of the mandibular arch and above the maxillary lobe," and that a certain amount of homology exists "between the spiracle of fishes and the lachrymal duct." From an examination of the young Porbeagle, it was sufficiently evident that the pouch from which the delicate spiracular canal opened to the exterior lay immediately in front of the hyoid

¹ *Report of the British Association*, 1885, p. 1069.

arch. In every respect, except in size, it corresponded to the first branchial cleft. As the first branchial cleft lies between the hyoid and first branchial arches, the spiracular or hyomandibular pouch lies between the hyoid and Meckel's cartilage, and hence must I imagine be considered as post-oral in position.

NEW METHODS OF IMBEDDING FRESH AND HARD-ENED TISSUES. By W. F. ROBERTSON, *Student of Medicine in the University; Assistant to Dr Russell in the Pathological Department of the Royal Infirmary, Edinburgh.*

THE methods of imbedding fresh and hardened tissues, of which a description is given in this paper, have recently given results of such a kind as to render the publication of a brief account of them desirable. They have been under trial for a good many months, and they are now submitted to the attention of histologists as an auxiliary to the methods at present generally in use,—not as a substitute for them. It is believed, however, that they present certain advantages. These are (1) that permanent sections of fresh tissues may be obtained by the process; (2) when from delicacy of structure the freezing method is not suitable, as is often the case with stomach, spleen, &c., the methods yield very satisfactory results.

Method A.

(1) *For Fresh Tissues.*—The materials necessary for imbedding by this method, and the proportions required, are as follows:—

Grape-sugar,	.	.	5 parts by weight.
Dextrine,	.	.	10 parts „
Boracic acid,	.	.	1 part „

To every quarter ounce of this composition add three drachms of water. Dissolve by bringing to the boiling point, and when cool add about six drops of carbolic acid to every fluid ounce. This solution must always be used freshly made. A quantity of the dry ingredients in the above proportions, after being thoroughly mixed in a mortar, may be kept in a stoppered bottle ready for use as required. The pieces of fresh tissue it is desired to imbed should not be very large, but they should not be less than one-eighth of an inch in thickness. They should

be barely covered by the imbedding solution. A convenient form of vessel to use for imbedding is a paper boat of strong paper, similar to those commonly used in the paraffin method, and of a size varying according to the number of pieces to be imbedded. Any shallow dish, however, will do equally well. The process of saturation, which requires from twenty-four to thirty-six hours, should be carried on in a warm dry place, but the temperature should not exceed the ordinary temperature of a room. After about twelve hours' immersion the pieces should be turned. The object of using less of the solution than is sufficient to cover the tissues, is that concentration of it may readily take place while the process of saturation is going on. Care must be taken, however, that evaporation does not take place too rapidly. If the solution is allowed to become concentrated to a thick syrup, the effect upon most tissues is, that they do not, in the subsequent process of drying, attain a proper consistence for cutting. What is really wanted is that, before the pieces are taken out, the solution should have reached a degree of concentration rather greater than what would correspond to a solution containing two drachms of water to every quarter ounce of the dry composition. It has been found that if only a solution of this final strength is used, and the pieces of tissue completely submerged, and evaporation prevented, in many cases, especially if the specimens have been hardened, an inconveniently long time is required for complete saturation. Thorough saturation, with a minimum of subsequent contraction, is secured by using the imbedding material in the manner indicated.

After the tissues have been allowed to remain in the imbedding fluid for from twenty-four to thirty-six hours, they should be taken out and allowed to dry on non-absorbent paper. The process of drying, like the process of saturation, requires to be carried on in a warm dry place. No attempt, however, must be made to hasten the process by placing the tissues in a heated chamber, such as a water-bath, for if this is done they are completely spoiled. It is essential that they should be allowed to dry very slowly. Simple exposure of the pieces to the action of the air will usually result in the process being carried on at a proper rate, but occasionally, when the air is very dry, it will be

found that the pieces when thus exposed are liable to be spoiled by too rapid hardening taking place, and this contingency must be carefully guarded against. It may be stated, as a rule, that drying is going on too quickly if, after twelve hours' exposure to the action of the air, the pieces are seen to be quite free from any moisture on their surface. Means must in such cases be taken to check the rapidity of the process. This may readily be done by placing the preparations under a glass bell-jar, or any other suitable apparatus, on a flat surface, so as to limit the amount of air acting upon them. Occasionally it may be necessary to place a small piece of damp filter-paper within the chamber thus formed; but, as a rule, drying will be found to be sufficiently retarded without it. In from two to five days, if the drying process has been properly managed, the pieces of tissue will be found to be of such a consistence as to permit of thin dry sections being cut with the microtome.

In order to ascertain whether or not a tissue is ready to cut, it must be carefully tested with a sharp razor. After a little practice, one readily gets to know when the drying process has been allowed to go far enough. The consistence should be very much the same as that of tissues imbedded in paraffin, but slightly tougher. When pressed with the finger nail, the surface should not readily indent. The tissue, having thus been ascertained to be sufficiently firm to cut, should without further delay be dipped for a few seconds in melted hard paraffin. A thin coating is all that is necessary, but it must be complete. Great care must be taken that the paraffin is not used too hot. It requires to be heated only one or two degrees above its melting point. A quality that melts at 45° C. does very well. When once a coating of paraffin has been in this way applied, and has been allowed to cool, the tissue is readily fixed to the platform of the microtome with the aid of a hot wire and a small quantity of additional paraffin. If it is not convenient to cut it at once, it may be set aside for a time, as the coating of paraffin, if properly put on, prevents further evaporation and consequent overhardening.

(2) *For Hardened Tissues.*—Hardened tissues may be imbedded by the same method. They should, however, be previously steeped for from twelve to twenty-four hours in water,

and they should be allowed to remain in the grape-sugar fluid for forty-eight hours. The process is otherwise exactly the same as that described for fresh tissues.

Sections of fresh and hardened tissues, cut by this method, have the imbedding material washed out of them by immersion for one minute in ordinary water. The rim of paraffin round them readily separates, and rises to the surface. It is of importance that they should be at once forced down into the water, and not merely allowed to float on the top. The sections of fresh tissues stain very rapidly and brilliantly with picrocarmine.

Method B.

For Hardened Tissues.—The materials required for this method are as follows:—

Grape-sugar,	.	.	5 parts by weight.
Dextrine,	.	.	10 parts „
Sapo mollis,	.	.	2 parts „

Add three drachms of *distilled* water to every quarter ounce of this material. Dissolve by boiling, and when cold add about six drops of carbolic acid to every fluid ounce. A stock of this composition may be made by dissolving a suitable quantity of the necessary ingredients in the above proportions in as small a quantity of distilled water as possible, with the aid of gentle heat. Further concentration should be effected by keeping at a temperature a little below the boiling point for several hours. The solution used for imbedding must always be freshly prepared. The pieces of tissue to be imbedded should be previously steeped for at least twelve hours in ordinary water, and then for an hour in distilled water. They are sufficiently saturated by about thirty-six hours' immersion. They should be set out to dry on filter-paper. Otherwise the details of the process are the same as for Method A. Sections cut by this method have the imbedding material dissolved out of them by from five to ten minutes' immersion in distilled water. The use of distilled water in this case is essential.

With hardened tissues Method B is more easily managed than Method A, and is more generally applicable. The tissues do not so rapidly become too hard to cut, and there is, on this

account, less risk of failure from their not being dipped in paraffin in time. Method A is not recommended for imbedding unconsolidated lung, very delicate tissues, or tissues which have been rendered in the least degree brittle by over-hardening. It may be safely employed, however, with any solid organ which has not been over-hardened; and it has the advantage that sections cut by it have the imbedding material readily dissolved out of them by ordinary water.

In regard to the imbedding of fresh tissues, it is to be noted that, in cases where a markedly septic organ, such as stomach, intestine, or phthisical lung is being treated, it is necessary to render it aseptic by immersion for an hour or longer in weak carbolic lotion before putting it into the imbedding fluid.

In dealing with fresh stomach or intestine, when not greatly thickened by morbid growth, it is well to imbed a much larger piece than it is desirable to fix on to the microtome. A piece about half a square inch in size should be taken. From this a portion of suitable size may be clipped off when the drying is completed, and fixed on to the microtome in the way described above. As regards staining, the best results with fresh stomach and intestine have been obtained by staining *en bloc* for forty-eight hours in alum-carmines, to which has been added a few drops of carbolic acid, and then completely immersing for twenty-four hours in the grape-sugar fluid (Method A), using a solution with only two drachms of water to every quarter ounce of the dry composition. If a very strong alum-carmines solution is used, the staining may be effected in less than twenty-four hours. As all the materials used in Method A are soluble in glycerine, sections of stomach or intestine prepared in this way may, if desired, be immediately mounted into thin Farrant's solution.

Sections of tissues imbedded by these methods have been successfully cut with the Cambridge rocking microtome, and with the microtomes of Bruce, Rutherford, Cathcart, and Swift. It is, perhaps, hardly necessary to state that, as in the case of successful section-cutting by any other method, the knife used must be extremely sharp. As a rule, it is well to allow sections that have just been cut to lie spread out on a sheet

of paper for twelve hours or so to finish the drying. They may then be stored in chip-boxes without any risk of their adhering to each other. If protected from damp, they will keep indefinitely.

It is proposed to call these methods the *grape-sugar imbedding methods*.

THE PROSTATE GLAND: ITS ENLARGEMENT OR
HYPERTROPHY. By JOSEPH GRIFFITHS, M.B., C.M.
Edin., *Assistant to the Professor of Surgery in the
University of Cambridge.* PART III. (PLATE XIV.)

HAVING already in Part I. (*Jour. of Anat. and Phys.*, vol. xxiii. p. 374) drawn attention to the development of the prostate gland, and pointed out that the gland-tubules form the essential structure of the organ, and having in Part II. (*Ibid.*, vol. xxiv. p. 27) shown the close relation that exists between the prostate and the testicles, not only in the lower animals during the rutting season but also in the higher animals and in man; and, besides, having accounted for the existence between and around the tubules of a large amount of non-striped muscle, which serves chiefly as the mechanism for the expulsion of the secretion of the gland into the urethra, I shall now endeavour, with the aid of the above facts as a basis, to give the pathology of the commonest morbid affection to which this gland is liable. The liability to this affection occurs during the period of life which is characterised by the commencement of decline in, and almost total disappearance of, the sexual power. Although the prostate, like the testicle, diminishes in size during that period, and undergoes the physiological atrophy of old age, yet in as many as 30 per cent. of persons above the age of 50 years, according to Sir Henry Thompson,¹ this gland becomes enlarged, and gives rise in many instances to urinary troubles which may or may not prove directly fatal. The enlargement is most frequently met with between the ages of 60 and 70 years. Regarding the prevalence of enlarged prostate in the aged, it will be observed that Professor Humphry, in his work on *Old Age and the Changes Incidental to it* (1889), says that 17 only out of 72 persons between the ages of 80 and 90 years, and 1 only out of 30 above 90 years, suffered from the urinary troubles that are referable to this affection of the prostate.

¹ *Diseases of the Prostate.*

It is clear, therefore, that in a certain proportion of men above the age of 50 years, the prostate gland—an accessory sexual gland as it seems to be—abnormally increases in size after the commencement and during the period of cessation in sexual activity; and this increase, as will be shown further on, is due to a growth of the gland-tubules. Thus more gland substance is formed, but it is obviously of inferior quality, forasmuch as it is not endowed with the same property of resisting degenerative changes, and the same powers of producing secretion as the normal gland. Such secretion as is formed by the enlarged gland is scanty, thin, and watery, whereas that from the normal gland is abundant, and contains more mucus, so that the increase in the amount of glandular substance is associated with diminution in quantity and deterioration in quality of the secretion.

I propose at present to confine myself to a discussion on the nature of the changes that take place during the enlargement of the prostate, and the effect directly resulting upon the prostatic portion of the urethra and the bladder. I may first refer to the fact that in a large proportion of men the prostate is represented only by two lateral lobes; while in others, as I have shown in this *Journal*, vol. xxiii. p. 375, there exists in addition, between and above the lateral lobes, a certain and variable amount of prostatic substance, the glandular tubules of which are originally derived from that part of the hinder wall of the urethra extending from the *verumontanum* to the neck of the bladder. This portion occupies the situation assigned by Home and others to the “*third*” or median lobe.

Inasmuch as enlargement takes place from the abnormal growth of the pre-existing gland-tubules (see further on), it is evident that, unless there normally exists in a particular instance prostatic gland-tubules in the situation of the “*third*” or median lobe, there can exist no enlargement in that position.

When the gland enlarges as a whole, and equally in all its parts, then the prostate is increased in all its dimensions, that is to say, the lateral lobes are wider, longer, and deeper, and this is associated with a corresponding increase in the size of the “*third*” or median lobe when it is present. The gland, however, retains its original shape and form. Coincidentally

there occurs a corresponding increase in the width, length, and depth of the urethral channel; and the channel may become further dilated so as to contain a drachm or more of urine, which is liable to trickle away (fig. 3). This not infrequently gives

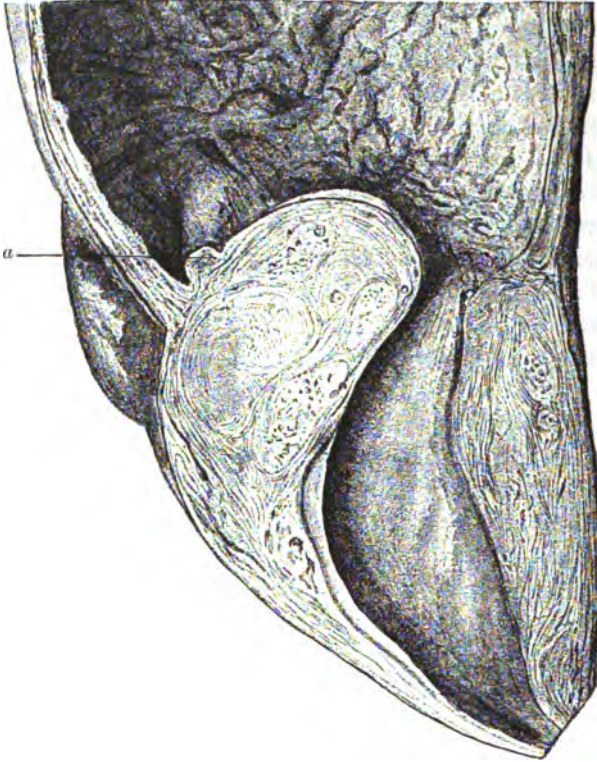


FIG. 3.—A Median Longitudinal Section of an enlarged Prostate, with Bladder, hardened with spirits. The prostate gland is enlarged as a whole, and the urethra is elongated and much increased in capacity. There is no enlargement behind the urethra except in the position of the "third" or median lobe, which has grown upwards into the bladder, pushing before and thinning out the greater part of the trigone, the hinder edge of which is indicated by the letter *a*. The vesico-urethral orifice is greatly enlarged, especially from side to side. The bladder is hypertrophied and fasciculated, and the usual pouch behind the inter-urethral bar is seen in its earliest stage of formation. The urethra is remarkably dilated at the base of the "third" lobe.

rise to the impression that the catheter has entered the bladder while it is still only in the prostate. In the two examples from which these drawings were made, there was uniform enlargement of the whole gland, the one being an instance

of the presence of the "third" or median lobe, and the other the total absence of that lobe (fig. 4). As is well known, the different parts of the gland may enlarge unequally, or only one

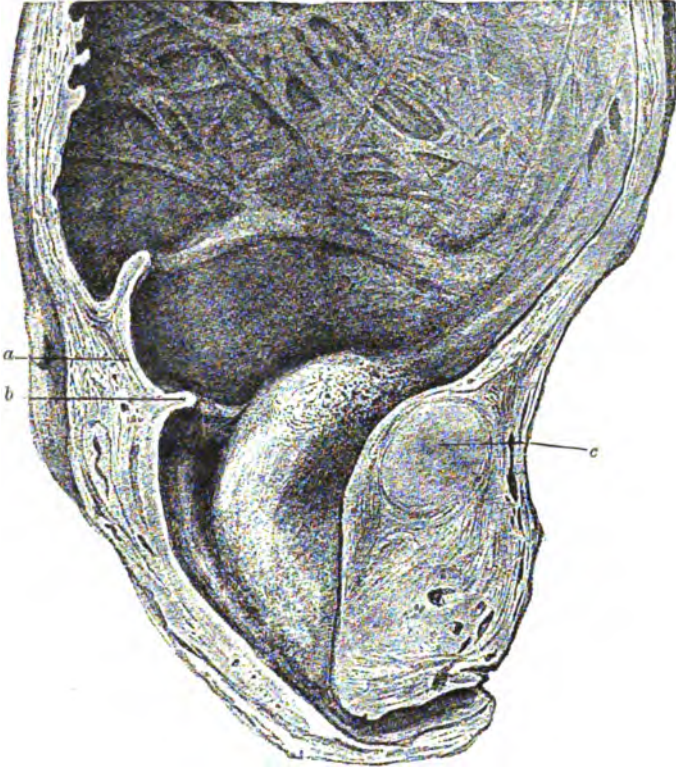


FIG. 4.—A similar Section, prepared in the same way, of an enlarged Prostate, with the Bladder. The prostate is enlarged in both lateral lobes, but no enlargement whatever in any part behind the urethra; there is therefore no trace of gland-substance in the situation of the "third" lobe. The urethra is much increased in all directions, and also the urethro-vesical orifice, which is partially filled by a finger-like process from the enlarged left lobe. There is in the enlarged anterior wall of the prostate, near the bladder, a small, round, circumscribed mass, which is a pure myoma (c). The bladder is much hypertrophied and fasciculated; the pouch behind the inter-uretral bar is more pronounced than in fig. 3; and as there is absence of the "third" lobe, the trigone, a, is normal, and the bar, b, at the neck of the bladder is rendered very prominent.

part enlarge, as is not unfrequently the case with regard to the "third" or median lobe. Besides, there occurs unequal enlargements of the different parts of the same lobe in some instances.

Unequal enlargements, whether of the lobes or of parts of the lobe, will necessarily give rise to various kinds of distortion in the urethral canal, amongst which may be mentioned, as perhaps the most important, the sharp or almost angular curve in the mesial plane produced by enlargement of the "third" lobe; or there may be a deviation to one or other side depending upon unequal enlargements of the lateral lobes. There may also be a collar-like ring surrounding the vesico-urethral orifice and projecting into the bladder. This latter, however, so far as I have observed in various collections of enlarged prostates, is not by any means frequently met with. Numerous, indeed, are the forms assumed by enlarged prostates and the contained urethra; and, as they are so well known and fully described in general text-books on this subject, I need not do more than refer to them here. There is, however, one point in the naked-eye anatomy of the enlarged prostate that has not hitherto attracted much attention—it is, that enlargement does not take place in that part of the gland which lies behind the urethra and anterior to the *verumontanum*. In the normal and fully developed prostate the glandular substance is found mainly on each side of the urethra, very little if any behind the urethra, except in the situation of the "third" or median lobe, where it may be absent or present in variable amount.

In the accompanying figures (3 and 4) it will be observed that there is not in either specimen any enlargement of the gland behind the urethra anterior to the *verumontanum*; and I have found the condition to be the same in all the instances of enlarged prostates that I have had an opportunity of dissecting, and of those which I have seen in the Cambridge and other pathological museums. This fact has long been made use of clinically in cases where there occurred any difficulty in the introduction of the catheter for the relief of prostatic retention, because the instrument can be here felt *per rectum*, and it may be tilted upwards by means of the finger so as to facilitate its passage over an enlarged "third" lobe into the interior of the bladder. Besides, it may prove of considerable value in differential diagnosis between simple enlargement or hypertrophy and the enlargements which result from malignant disease. I make this remark because malignant disease, both in the child and

adult, affects especially the region of the gland behind the urethra.

As the prostatic urethra dilates, so do the ducts of the prostate which open into it; these latter dilate in some instances even to such a degree as to admit, with comparative ease, the point of a medium-sized catheter. This becomes of practical importance when enlargement of the "third" or medium lobe occurs, for in such cases the urethra is most dilated, and the enlarged ducts of this lobe open in the situation where the end of the catheter is likely to impinge. The catheter may be in such cases pushed into these dilated ducts, and through the enlarged and altered gland, either into the bladder or into the surrounding pelvic tissues, so as to form false passages, which were not of unfrequent occurrence in the days when rigid instruments were in more frequent use than they happily now are.

The enlargement of the prostate really presents in most instances two stages, of which the first may be called the *glandular*, forasmuch as it consists mainly of glandular or modified glandular tissue, with its due proportion of muscular tissue, which closely resembles that of the normal gland; and the second may be called *fibrous*, forasmuch as in it the glandular and muscular tissue have in great part disappeared from atrophy, and are replaced by old and fibrous connective-tissue.

The First or Glandular Stage.

In the earlier stages of enlargement the gland merely presents a coarser structure than normal. Often when more advanced it presents a number of small masses of gland-substance, separated from one another by trabeculae of fibrous or fibro-muscular tissue, which traverse it in all directions. The spaces thus enclosed vary up to one-third of an inch in diameter, the commonest size being about one-sixth of an inch. The gland-tubules in many of these small glandular areas have become dilated so as to form minute cysts, which as a rule do not exceed a line in diameter, and which contain an albuminous fluid readily coagulated by treatment with alcohol. Some of the larger masses projects on the surface of a recent section. They are more or less distinctly circumscribed, and a few of these may be easily enucleated when they have undergone the fibrous degenerative changes which charac-

terise the *second* or *fibrous* stage. It is these larger masses that have attracted so much attention from various writers on the enlarged prostate, and which are usually described as "tumours." More will be said in regard to the real nature of these tumours further on. On microscopic examination at this early stage the lobules of the enlarged gland are seen to be composed of a structure which is in parts almost identical with that of the normal gland; the gland-tubules are of normal size and shape, with the usual papillary projections into the interior, and are lined by a single layer of tall columnar epithelial cells, resting on a basement membrane of flattened epithelial cells, and are separated from one another by connective-tissue bands which contain a considerable amount of non-striped muscle-fibres. In other parts the gland-tubules are dilated, and have lost the convoluted character of their lining, so as to form minute cysts. Such of the cysts as are in the earliest stages of formation are still lined by the same kind of epithelium as the normal tubules, namely, a single layer of tall columnar epithelial cells; but the larger are lined only by a single layer of flattened epithelial cells, which in all probability corresponds to the basement membrane found in the normal gland-tubule already described in Part I. (this *Journal*, vol. xxiii. p. 378). These cysts usually contain a more or less homogeneous colloid-like substance, which is evidently derived from degenerative changes taking place in the cast-off epithelial cells. That this is so, may, in some instances, be directly traced (Pl. XIV. fig. 1). The stroma or intertubular tissue of the enlarged gland closely resembles that of the normal gland, and, like it, contains a large amount of non-striped muscle. There are, however, in the stroma small collections of round cells, which resemble leucocytes, scattered here and there like so many foci of inflammation; but, so far as I can observe, there are no farther evidences of inflammation in the rest of the stroma.

The Second or Fibrous Stage.

This stage may be found limited to small areas of the enlarged gland, or it may involve the entire gland, and thus convert the whole into a firm, hard, and fibrous mass. The areas of limited fibrous transformation are best seen in the larger

glandular masses just referred to in the naked-eye description of the first or glandular stage. It is brought about by gradual atrophy of the gland-tubules and of the muscle-fibres in the stroma by the substitution for them of fibrous connective tissue. Thus the once glandular mass is transformed into a mass of fibrous connective tissue, containing only the atrophied remains of the gland-tubules and of the non-striped muscle. We have here, then, a good example of the disappearance of the more highly specialised elements of a tissue and their replacement by a less specialised form which is capable of existing on the minimum amount of nourishment. Where such a change involves the enlarged gland in its entirety, as it occasionally does, the same appearances may be seen scattered more or less uniformly throughout its substance, as seen in Plate XIV. fig. 2. This, which I regard as the *latter* or *second* stage in hypertrophy of the gland, corresponds to the fibrous variety of former writers. Although it occurs only occasionally throughout the enlarged gland, yet it may be found in most examples of enlarged prostates in some of the small glandular masses. Further, I find this change to be associated with very marked alterations in the walls of the larger blood-vessels of the gland, which produce a great diminution in their lumen. This diminution in their lumen results from fibrous thickening of the internal and also of the middle tunics of the vessels. Such a form of arterial change is well known to be accompanied in other organs, as well as the prostate, by fibrous changes in the tissues supplied—in the kidney, for example; and it is considered by Zeigler and others to be the primary cause of the fibrous changes often observed in that organ.

From the foregoing description of enlargement of the prostate gland, it will be observed that enlargement or hypertrophy originates from a growth of the gland-tubules, and that after a variable time atrophy of the gland-tubules and of the muscle in the stroma is liable to supervene, and the place of the hypertrophied glandular tissue to be taken by fibrous connective tissue.

These successional changes constituting my first and second stages scarcely accord with the views of Sir Henry Thompson as given in his work; still less with those of Mr Reginald

Harrison,¹ who, following out his ideas of the muscularity and sphincter action of the prostate, regards the enlargement as due to hypertrophy of the muscle taking place, to compensate for an increased call for a sphincter action in men as they advance in years.

Respecting these ideas, I have already given my reasons for dissent (see Part I., vol. xxiii. p. 383).

The exact nature of the so-called TUMOURS found so frequently in the enlarged prostate has been discussed by most writers on this subject.

Cruveilhier,² Sir Henry Thompson,³ and others regard these little masses as identical with the *fibroids* or *myomata* of the uterus. This view is based upon their occurrence in numbers upon the presence of muscle in them, and upon the supposed homology between the muscle of the prostate, from which they are said to originate, and that of the uterus; whereas Rokitanski,⁴ Socin,⁵ and others look upon these as similar in all respects to the localised glandular tumours frequently found in the mammary gland. The former observers place the muscle elements in the foreground, maintaining that the presence of gland-tissue is accidental, whereas the latter hold the gland-tissue to be the essential and important constituent.

Socin,⁶ rightly I think, observes that these little masses are never without any glandular tissue, and that the amount of the glandular tissue varies with the age of the mass—that is to say, that when it is recent it contains relatively a greater proportion of glandular tissue than when it is old. He would even go further, and give this little mass the appellation *adeno-myoma*, thus placing it among the tumours proper. They are, however, not in reality tumours in the accepted sense of the term, but merely, as I have already intimated, pronounced local enlargements of the gland, passing through the same stages as the gland when enlarged as a whole; and, so far as I am able to

¹ *Surgical Disorders of the Urinary Organs*, Lect. xxiii.

² *Anat. Pathologique*.

³ *Loc. cit.*

⁴ *Zur Anat. des Kropfes*, s. 10.

⁵ *Hand. der Chirurg. Von Pitha. und Billroth*, Bd. iii. Ab. ii. s. 39.

⁶ *Ibid.*

make out from macroscopic and microscopic investigations, they have no claim to be classed with the *myomata*, commonly found in the uterus. It is true, indeed, that pure *myomata* do originate from the non-striped muscle of the prostate, as indeed from any other non-striped muscle in the body, but these are of rare occurrence; and where they do occur they do not in their structure correspond with the localised masses or to the general enlargement of the gland above described.

It may perhaps be of interest to mention here an example of such a growth in a specimen in the Cambridge Museum, with the following description:—

“Tumours at the Neck of the Bladder and Prostate.”

There are two conical projections of the fore part of the prostate in the urethra near the bladder. One of these, cut into, is seen to be caused by the presence of a small round tumour invested with a distinct capsule of dense cellular tissue, which separates it from the surrounding substance of the gland. The tumour is solid throughout, and presents an appearance not unlike that of a mammary tumour.”

On microscopic examination of one of the tumours, I find that it consists almost entirely of muscular tissue, and is devoid of glandular substance—that is to say, a pure myoma.

A similar myoma may be seen, fig. 4, p. 239, in the same situation, this being, however, of larger size. It is the only example that I have met with in the specimens examined by myself.

Conclusions.

The chief conclusions arrived at in this paper are the following:—

1. That enlargement or hypertrophy of the prostate gland results from a growth of the gland-tubules with their associated muscle, so as to form new gland-substance, closely resembling in its structure the normal gland. This constitutes the *first* or glandular stage.

2. That after a variable time degenerative changes set in, which ultimately convert the new tissue into a mass of more or less dense, fibrous, connective tissue, containing only the atrophied remains of the glandular and muscular elements. This constitutes the *second* or fibrous stage.

3. That no enlargement takes place behind the urethra except when glandular substance exists behind and above the level of the *verumontanum* in the situation of the "third" or median lobe.

4. That the so-called "tumours" are not in reality *tumours*, but merely pronounced localised enlargements of the gland, which pass through the same stages as the gland when enlarged as a whole.

5. That true muscular tumours (*myomata*) do sometimes, though rarely, arise in the substance of the prostate gland, but that they are pathologically different from the ordinary local or general enlargement of the gland.

DESCRIPTION OF PLATE XIV.

Fig. 1.—A section taken from an enlarged prostate in the first or glandular stage, showing the altered and distended tubules and the presence in the stroma of non-striped muscle such as is seen in the normal gland. *a*, tubules closely resembling the normal, with convolutions or papillary projections into the lumen; *b*, dilated tubules in which the papillæ are obliterated, lined by cells in several layers, and partially filled with degenerated epithelial cells; *c*, other dilated tubules, lined by a single layer of flattened epithelial cells, and filled with a colloid mass; *d*, the stroma, containing much non-striped muscle-fibres.

Fig. 2.—A section taken from an enlarged prostate in the second or fibrous stage, showing the fibrous nature of the stroma and the degenerated masses of epithelial cells which represent the altered gland-tubules. *a*, spaces filled with small and degenerated epithelial cells; *b*, fibrous stroma, containing no muscle fibres.

NOTE ON THE TRANSVERSE-HUMERAL, CORACO-
ACROMIAL, AND CORACO-HUMERAL LIGA-
MENTS, &c. By C. GORDON BRODIE, F.R.C.S., *Hon.*
Surgeon to Western General Dispensary, Demonstrator
of Anatomy at Middlesex Hospital Medical School.

(Read at Anatomical Society, March 1889.)

THE attention which has been devoted to the morphology of ligaments during the last few years induced me to record the following notes regarding the ligaments in relation to the shoulder-joint, and I shall deal first with a ligament strongly enough marked in the human subject to be described, although it has not as yet, I believe, found its way into our text-books.

The Transverse Humeral Ligament (fig. 3, T.H.L.).—In Man this ligament is represented by a broad band of fibrous tissue trapezoid in shape, passing from the lesser to the greater tuberosity of the humerus, and always strictly limited to that portion of the bone which lies above the epiphysial line. It thus converts the bicipital groove into a canal, and would strongly resist any dislocation of the long tendon of the biceps, which lies beneath it, and if torn would also account for the extreme difficulty experienced in keeping the tendon in its place, reduction being easily accomplished.

It is even more marked in the foetal humerus, being proportionately thicker to the relative sizes of the bones, approaching in thickness and strength to that found in the Gibbon.

On cutting sections of the foetal humerus a tract was found in the fibrous tissue forming the roof of the canal, well defined and presenting the appearance as though it had been at one time fibro-cartilage, and was degenerating into fibrous tissue. It gave the impression that pure cartilage could be found if an earlier foetus were attainable.

The ligament has been shown as existing in many mammals by Mr Sutton,¹ including the Lion, Tiger, and Bear. It also

¹ Sutton, *On Ligaments*, p. 6.

exists in Apes, and the accompanying sketch shows it well delineated in the head of the Gibbon's humerus, but differing from Man in this respect that it extends below the epiphysial line, gradually tailing off on the outer border of the groove; its greater thickness is, however, situated above the epiphysial line.



FIG. 1.—Humerus of Gibbon, showing transverse humeral ligament.

Next in order to this osseo-aponeurotic canal we come to the bicipital foramen, where, as in the Musk Ox (*Moschus moschiferus*), the summits of the two tuberosities are joined



FIG. 2.—Humerus of Musk Ox, showing bicipital foramen.

together by a strong process of bone, well shown in the accompanying figure.

To complete the series, we must turn to the humerus of the

Mole, where, as has been shown by Mr Austin Freeman,¹ the tendon plays in a complete osseous tunnel.

The presence of the degenerating tract of fibro-cartilage existing in the foetus, in the roof of the canal, appears to point strongly to the fact that metamorphosis has been at work rendering the once bony tunnel an osseo-aponeurotic canal.

Besides this, the Gibbon's humerus is remarkable in another way, for on examining the lower extremities a well-marked supra-condyloid foramen is seen filled up by a fibrous septum and thus entirely falsifying the notion that a passage exists for vessels from the front to the back of the bone. The Musk Ox has a similar foramen.

Coraco-Acromial.—For some time past the arrangement of the coraco-acromial ligament has been under observation, and instead of the triangular band, as formerly described, it is now usually spoken of as consisting of three portions,² two strong marginal bands and a thinner intervening portion. This last middle part is thin and diaphanous in character, containing rarely many fibres of true ligamentous tissue, and is often incomplete, the deficiency occurring near the coracoid process. The external of the two marginal bands is usually the stronger and broader, passing from the tip of the coracoid to that of the acromion, while the inner of the two bands, and more commonly the slighter, passes from the base of the coracoid, sending fibres oftentimes on to join the transverse or trapezoid ligaments. In this I must differ from Mr Morris' description, which makes the inner limb the stronger. I find also that the inner limb may be inserted anywhere along the coracoid, whereas the outer is constant. Now, when the pectoralis minor misses its attachment to the coracoid, and passing on is inserted into the capsule of the joint, it passes through the two limbs of the coraco-acromial ligament, and the central portion is partially or entirely absent.

If a human foetus be observed, it will be noticed that the outer limb of the ligament is always well marked, but the inner is not so, and it is also very peculiar that fibres pass from it on to the short tendon of the biceps.

In the two-toed Sloth (*Cholæpus*) the adult specimens have a

¹ *Jour. of Anat. and Phys.*, vol. xx. p. 206.

² Morris, *Anat. of Joints*; and Ellis, *Dissections*.

complete osseous bridge extending from the acromion to the coracoid, while in younger members of the same family a process of cartilage occupies its place.

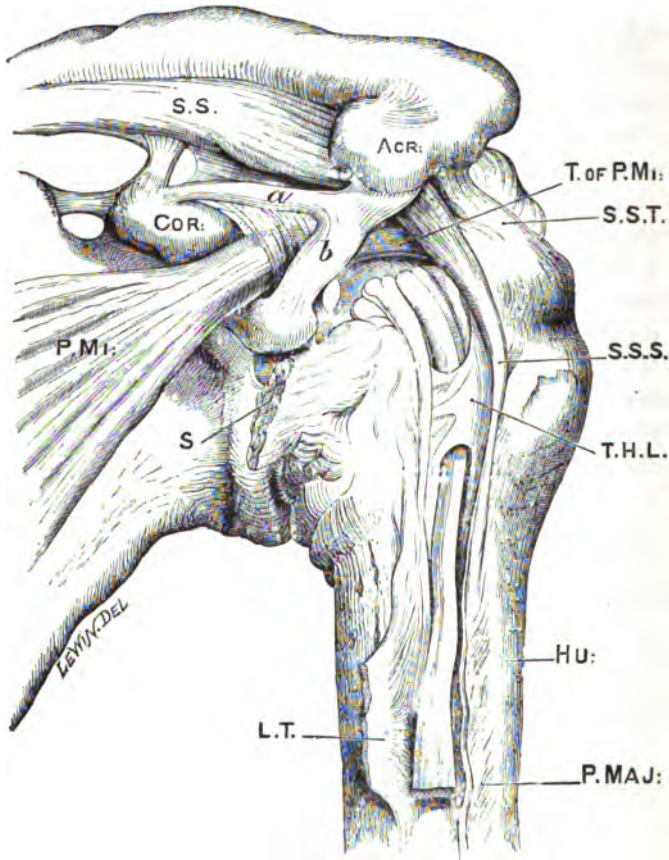


FIG. 3.—Showing the two bands of coraco-acromial ligament. *a*, inner; *b*, outer limb, with diaphanous centre. *N.B.*—The limbs are rather wider apart than is *usually* seen. P.Mi., pectoralis minor; T. of P.Mi., its tendon, replacing coraco-humeral ligament; T.H.L., transverse humeral ligament, with long tendon of biceps passing underneath; S.S., supraspinatus; S.S.T., its tendon inserted on to greater tuberosity; S.S.S., the slip from its tendon passing down to reach the pectoralis major; L.T., latissimus dorsi.

In *Bradypus* this ligament is apparently represented by a thickening in the aponeurosis covering the supraspinatus muscle, and passing in it from the apex of the coracoid to the

acromion is a narrow band of fibrous tissue lying in the edge of the thickened part, and in the line of junction of the trapezius and deltoid muscles. Mr Sutton states that in the foetuses of many mammals cartilage cells are found in the situation of the ligament.

It would thus appear *probable* that the coraco-acromial ligament is a compound structure, the outer limb representing the bony element of the Sloth; whilst it is possible that the inner limb has no morphological meaning.

The pectoralis minor has in several instances passed either completely or partially over the coracoid process, between the limbs of the coraco-acromial ligament into the coraco-humeral (fig. 3, T. of P.Mi.) and its attachment to the process, as well as the corresponding attachment of the coraco-humeral ligament, has varied inversely to the fibres which have so passed. In one case, where the whole tendon passed into the coraco-humeral, there was *no*, or at most a few, scattered fibres of the ligament anchored to the coracoid. The tendon might be well stated to be inserted into the greater tuberosity of the humerus underneath the supraspinatus, and hence would have proved a powerful inward rotator; and in the other cases, the greater the attachment of both ligament and tendon to the coracoid, the fewer fibres there were that passed over, showing thus pretty clearly that the ligament is the divorced *tendon* of the pectoralis minor.

Besides this, the ligament often has a short piece running from its inner border, and passing on to the margin of the glenoid cavity, nearly opposite the spine, not so very far from the fibrous band, the spino-glenoid ligament,¹ which stretches across from the external border of the spine to the edge of the cavity, so making the suprascapula artery and nerve pass under a fibrous arch. The ligament is thus Y-shaped, the broad single leg being attached to the coracoid, while the thicker broad leg runs to the great tuberosity, and the thinner leg passing to the border of the glenoid cavity.

In many of the same specimens there was a very distinct slip passing down from the supraspinatus muscle through the superficial fibres of the capsule, and becoming attached to the

¹ This is the *inferior transverse scapular ligament* of Henle.

ascending slip from the pectoralis major, which usually continues upwards to lose itself in the capsular fibres. In fact, the tendon of the supraspinatus may be fairly described as passing along the outside of the bicipital groove, and becoming inserted on to the surface, or joining some of the lower fibres. In most cases they spread out on the surface of the tendon of the pectoralis major in a fan-shaped manner. They were superficial to the coraco-humeral ligament, as figured in the woodcut (fig. 3, S.S.S.).

In one specimen the slips from the supraspinatus and pectoralis major were attached close together on the lesser tuberosity; in another it was connected with an aberrant slip from the latissimus dorsi; in two the ascending slip passed some of its fibres onward to the capsule beneath the coraco-humeral towards the coracoid; and the last had a complete bursal sac developed round it in its course through the capsule.

With these aberrant slips there was a partial splitting of the supraspinatus into two parts—an upper (or coracoid) and a lower one—next the spine (spinous), the former supplying the part of the tendon ending in the slip (S.S.S.), and the latter passing into the great tuberosity (S.S.T.). The former also ended in tendon much sooner than the latter.

Before closing, I must record my thanks to Mr Bland Sutton for many valuable suggestions and help given in the course of this paper.

THE CELL THEORY, PAST AND PRESENT. By Professor Sir WM. TURNER, M.B., LL.D., D.C.L., F.R.S.S. Lond. and Edin., *President of the Scottish Microscopical Society.*

[This article is the substance of an Address delivered at the Inaugural Meeting of the Scottish Microscopical Society, November 1, 1889.]

MR ROBERT HOOKE was one of the first men of science to employ the Microscope in the study of the structure of plants and animals. A chapter in his *Micrographia*¹ is entitled "Of the Schematisme or Texture of Cork and of the Cells and Pores of some other such frothy Bodies." This is probably the first use of the word CELL in histological description. In the course of this chapter he refers to the lightness of Cork, which he compares with froth, or an empty Honey Comb. Its substance, he says, is wholly filled with air, which "is perfectly enclosed in little Boxes or Cells distinct from one another." Further, he gives an idea of the dimensions of these cells by stating that about sixty could be placed endways in the $\frac{1}{8}$ th part of an inch, and that 1,166,400 could be placed in a square inch. He thinks that they are the channels through which the juices of the plant are conveyed.

The term Cell was also employed to express a definite morphological unit by Dr Nehemiah Grew,² who shares with Malpighi the glory of being one of the fathers of vegetable physiology. When describing in his *Anatomy of Plants* the skin of the root (p. 62), he says the parenchymous material is

"frequently constructed of exceeding little *Cells* or *Bladders*, which, in some Roots, as of Asparagus, cut traverse, and, viewed through a Microscope, are plainly visible. These Bladders are of different sizes; in Buglos larger, in Asparagus less, and sometimes they coincide and disappear."

In his account of the parenchyma of the bark he again uses the word Cells (p. 64), and says that

¹ London, 1665.

² *The Anatomy of Plants*, London, 2nd ed., 1682. The several Books into which Grew divided his treatise were presented to the Royal Society of London at various dates between 1671 and 1675.

"each is bounded within itself, so that the *Parenchyma* of the *Barque* is much the same thing as to its Conformation, which the Froth of *Beer* or *Eggs* is as a fluid, or a piece of fine *Manchet* as a fixed body."

These cells are so small as scarcely to be discerned without the microscope; more usually, however, Grew applies to them the term bladders or vesicles. In the chapter on the vegetation of roots he speaks of the sap swelling and dilating the bladders, and as being fermented therein, as transmitted from bladder to bladder, and leaving certain of its principles adhering to them. He thus recognised that the cells or bladders played an important part in the nutrition of the plant. Almost, indeed, he seemed to have grasped the idea that they exercised a selective or secreting influence; for, in describing the parenchyma of the fruit of the lemon, he speaks (p. 180) of "those little *Cells* which contain the essential Oyl of the fruit," whilst, he says, in other bladders, "lies the acid juyce of the limon."

Malpighi, whose work on the Anatomy of Plants¹ was almost cotemporaneous with the treatise of Grew, had also seen the structures which Grew named cells or bladders, and had designated them *utriculi*, and believed that they could be separated from each other. In a subsequent treatise² he described the lobules of fat in animals as consisting of adipose vesicles.

Leeuwenhoek, in the course of his microscopic inquiries into the structure of plants, gave the name of *globules* to many of the objects which we now term cells, though he expressly states that they were not perfect spheres.³

Clopton Havers, in his treatise on the skeleton, described⁴ the vesicular structure of the marrow, and compared it, when seen under the microscope, to a heap of pearls.

Alex. Monro, *primus*, in his work on the bones,⁵ when writing on the medullary structure, stated that it is sub-divided

¹ *Anatome Plantarum*, London, 1675.

² *Opera*, vol. ii. p. 41, 1686.

³ Samuel Hoole, who translated many of Leeuwenhoek's writings (London, 1799, part 2, p. 178), when describing fig. 11, on pl. vi., says that the globules of meal are enclosed as it were in cells, and that some of those cells are represented at H. in the figure. Leeuwenhoek himself, however, in his description of the same figure (*Epistolæ physiologicæ*, Delphis, 1719, p. 25), does not use the word *cellula*.

⁴ *Osteologia nova*, 1691, p. 167.

⁵ *Anatomy of the Humane Bones*, Edinburgh, 1st ed., 1726; 2nd ed., 1732.

"into communicating vesicular Cells, in which the Marrow is contained. Hence it is that the Marrow, when hardened and viewed with a Microscope, appears like a Cluster of small Pearls. This Texture is much the same as what obtains in the other cellular parts of the Body where Fat is collected, only that the Cells containing the Marrow are smaller than those of the *Tunica adiposa* or *cellulosa* elsewhere."

Caspar F. Wolff¹ also recognised that fat was contained in small vesicles, surrounded by a fine membrane. He conceived also that the developing organs, both of plants and animals, consisted of a viscous substance which contained cavities, cells, or bladders which communicated with each other.

Fontana figured the fat vesicles, both free and surrounded by the fibres of the areolar tissue.²

Mirbel, in his botanical writings,³ published at the beginning of the present century, stated that vegetables were composed largely of cells. He described *le tissu cellulaire* as composed of *les cellules*, which were contiguous with each other, so that the walls were in common. These walls were extremely thin and translucent, and sometimes riddled with pores. The term cells was also used both by his contemporaries and successors in their writings on the anatomy of plants.

But anatomists experienced much greater difficulty in distinguishing the presence of cells in the textures of animals. It is true that from the time of Malpighi and Leeuwenhoek, the globules or particles had been recognised in the blood, but it is only within a comparatively recent period that their cellular structure was determined. Both Bichat⁴ and Béclard,⁵ in their important treatises on General Anatomy, made no reference to cells as elements of the tissues. Both these authors had chapters *du tissu cellulaire* or *du système cellulaire*, a term which had

¹ *Theoria Generationis*, editio nova, 1774; Commentary "*Ueber die Nutritionskraft*," by Blumenbach and Born, St Petersburg, 1789.

² See his Essay "*sur la structure primitive du corps animal*" in his "*Traité sur le venin de la Vipère*," Florence, 1781 (Ph. viii. figs. 19, 20).

³ *Traité d'Anatomie et de Physiologie végétales*, t. i., Paris, au x.; *Exposition de la Théorie de l'organisation végétale*, Paris, 1809. Ch. Robin, in the article "Cellule," *Dict. Encyclop. des Sciences médicales*, Paris, 1873, credits Mirbel with having introduced the term "cellules," but the extracts given in the text show that its English equivalent, cells, had been in use for upwards of a century before Mirbel wrote.

⁴ *Anatomie générale*, Paris, 1812.

⁵ *Éléments d'Anatomie générale*, Paris, 1823.

been in use from the early part of the last century. But by the *tela cellulosa* or cellular tissue, anatomists meant that form of tissue which we now more appropriately call areolar tissue; the so-called cells of which are not microscopic closed vesicles, but areolæ or spaces bounded by the fibres or laminæ of which the tissue is chiefly composed.¹ Béclard, in his description of the adipose tissue, stated that the lobules of fat consisted of microscopic vesicles $\frac{1}{100}$ to $\frac{1}{800}$ of an inch in diameter. The vesicles, he says, have walls, but they are so thin as to be indistinguishable. The presence of organised vesicles or globules in the tissues of animals had thus been recognised, but it needed further observations and facts in order to bring them into association with the cells of vegetable tissue.

This was supplied by the discovery in 1831 by the great English botanist, Robert Brown, of the "nucleus" or "areola" in the cells of the epidermis, and other tissues in Orchidæ and many other families of plants.² Following closely upon this discovery were the observations of Schleiden, published in 1838,³ that the nucleus was a universal elementary organ in vegetables. Schleiden also came to the conclusion that the nucleus must hold some close relation to the development of the cell itself, and he consequently called the nucleus a "cytoblast." Schleiden further discovered that the cytoblasts contained one or more minute circumscribed "spots," or "rings," or "points," which he considered to be formed earlier than the cytoblasts, and which were regarded by him as hollow globules, and were subsequently named by Schwann "nucleoli."⁴

The cellular structure of some of the animal tissues had also begun to be recognised. Turpin had noticed the resemblance between the epithelium corpuscles found in vaginal discharges and the cells of plants. Johannes Müller had discovered that

¹ The term cellular tissue was originally applied to this texture from a fancied resemblance to the proper cell tissue of plants; the walls of the cells of which were believed to be formed of a framework of fine fibres.

² "Organs and Mode of Fecundation in Orchidæ and Asclepiadæ," *Trans. Linn. Soc.*, vol. xvi., 1833; reprinted in *Miscellaneous Botanical Works*, vol. i. p. 511, Ray Society edition.

³ "Beiträge zur Phytogenesis," *Müller's Archiv*, 1838, p. 137.

⁴ Fontana (*op. cit.*) figured the "globules" or scales of the epidermis, in which he recognised the nucleus, but he neither gave it a special name, nor knew its importance (plate i. figs. 8, 9, 10).

the chorda dorsalis of fishes was composed of separate cells provided with distinct walls, though he did not detect a nucleus in them. Purkinje, Von Baer, Rudolph Wagner, Coste, and Wharton Jones had seen the germinal vesicle within the animal ovum. E. H. Schultz had observed the nucleus in the blood globules, and Valentin and Henle had seen it in the cells of the epidermis. The way was thus prepared for a fuller recognition of the essential correspondence between the elementary tissues of plants and animals and for a wider generalisation. Science had not long to wait for an observer who could take a comprehensive grasp of the whole subject; and in 1839 Theodore Schwann published¹ his famous researches into the structure of animals and plants, in which he announced the important generalisation that the tissues of the animal body are composed of cells, or of materials derived from cells:—

“That there is one universal principle of development for the elementary part of organisms, however different, and that this principle is the formation of cells.”

Both Schleiden and Schwann entertained the idea, which had long before been present in the mind of Grew, that a cell was a microscopic bladder or vesicle. In its typical shape they regarded it as globular or ovoid, though capable of undergoing many changes of form. This vesicle possessed a cell-membrane or wall, which enclosed contents that were either fluid or somewhat more consistent. Either attached to the wall or embedded in it was the nucleus, which in its turn contained the nucleolus. Schwann, however, recognised² that many cells did not exhibit any appearance of a cell-membrane, but seemed to be solid, and had their external layer somewhat more compact. As showing, however, the importance which Schwann attached to the cell-wall, I should state that he regarded the chemical changes or metabolic phenomena as he termed them, as being chiefly produced by the cell-membrane, though the nucleus might participate. He explained the distinction between the character of the cell contents and the cyto-blastema external to the cell, to the power exercised by the cell-membrane of chemically altering

¹ “*Mikroskopische Untersuchungen*,” 1839; and Preliminary Notices in *Forriep's Notizen*, 1838.

² P. 176 of Sydenham Society's translation of *Schwann's Memoir*.

the substances, which it is either in contact with or has imbibed, and also of separating them so that certain substances appear on the inner and others on the outer surface of that membrane. In this way, he accounted for the secretion of urea by the cells lining the uriniferous tubes, and for the changes which not unfrequently take place in the cell-membrane itself by thickening or deposition of layers on or within it.

Schwann described the nucleus as either solid or hollow and vesicular, in the latter case being surrounded by a smooth structureless membrane; whilst the contents of the nucleus, other than the nucleoli, were in his view either pellucid or very minutely granulous.

Both Schleiden and Schwann conceived that in the formation of a nucleus a nucleolus was first produced, that around it new molecules were deposited for a certain distance, and then a nucleus was formed. When the nucleus had reached a certain stage of development, new molecules were deposited upon its exterior so as to form a stratum, which when thin was developed into a cell-membrane, but when thick only its outer portion became consolidated into a cell-membrane. Immediately the membrane became consolidated its expansion proceeded by the progressive reception of new molecules; the cell-wall separated from the cell nucleus, and a vesicle was formed; the intermediate space at the same time became filled with fluid, which constituted the cell contents.

Schleiden contented himself with little more than a simple statement of what he conceived to be the process of cell formation in plants; but Schwann entered into an elaborate survey of cell-life both in animals and plants, and founded on it a theory of cells applicable to all organisms.

Schwann conceived that there existed in organised bodies a solid amorphous or fluid substance to which he gave the name *cytoblastema*; this substance might be contained either within cells already existing, or else be situated in the interspaces between cells; and he believed that the cytoblastema for the lymph and blood corpuscles is the fluid lymph-plasma and liquor sanguinis in which these corpuscles float. He held that in the cytoblastema new cells are formed in the manner just described. In animals he says it is rare for cells to arise within pre-

existing cells; more usually they arise in a cytoblastema external to the cells already present. Schleiden, on the other hand, maintained that in plants new cells were never formed in the intercellular substance, but only within pre-existing cells. The idea obviously present in the mind of Schwann was that the process of cell formation in a cytoblastema had some affinity with that of crystallisation. He figuratively compares the cytoblastema to a mother liquid in which crystals are formed. He speaks of molecules being deposited around a nucleolus to form a nucleus; of a nucleus growing by a continuous deposition of new molecules between those already existing; and of the cell being formed around the nucleus by a progressive deposition of new molecules; and in more than one passage he indicated that this deposition is a precipitation. He obviously considered the principle of formation of the cell around the nucleus as the same as that of the nucleus around the nucleolus, a process which Valentin subsequently described as heterogeneous circum-position.

But Schwann at the same time showed that, with reference to the plastic phenomena, cells differed from crystals in form, structure, and mode of growth; for whilst a crystal increases only by the external apposition of new particles, a cell grows both by that method and by the intussusception of new matter between the particles already deposited. The difference, he says, is yet more marked in the metabolic phenomena, which he conceived to be quite peculiar to cells. Cells and crystals, however, he considered resembled each other in this point, that solid bodies of a definite and regular shape are formed in a fluid at the expense of a substance held in solution by that fluid, for both attract the substance dissolved in the fluid. Schwann concluded his memoir by advancing, as a possible hypothesis, the view that organisms are nothing but the form under which substances capable of imbibition crystallise; and although this hypothesis involves very much that is uncertain and paradoxical, yet he considered it to be compatible with the most important phenomena of organic life. Schwann inclined, therefore, to a physico-chemical explanation of cell-formation and cell-growth.

Shortly after the publication of Schwann's famous memoir, Henle, who had for some years been engaged in microscopic

investigations on the tissues, published his well-known treatise on General Anatomy.¹ He attached great importance in cell formation to extremely minute particles, $\frac{1}{8000}$ to $\frac{1}{12000}$ of an inch in diameter, which he called *elementary granules*. He conceived that these appeared in a blastema, that several aggregated together to form a nucleus, in connection with which he thought it not improbable that a cell subsequently formed. He looked upon the elementary granules as the first and most general morphological elements of the animal-tissues, and he regarded them as vesicles consisting of excessively minute particles of oil coated with a film of albumen. It should be stated that Henle's observations on cell formation were conducted to a large extent on the products of inflammation, and on the lymph and chyle, in all of which fatty and granular particles abound.

As regards the part which the nucleus plays in the process of cell formation, both Schleiden and Schwann regarded it as of prime importance, though in the subsequent life of the cell they considered that its function terminated. Schleiden stated that, subject to certain exceptions which he enumerated, it is rare for the cytoblast to accompany the cell through its entire vital process—that it is often absorbed either in its original place, or cast off as a useless member, and dissolved in the cavity of the cell. Schwann, whilst contending for the exceedingly frequent, if not absolutely universal, presence of the nucleus, yet held that in the course of time it usually became absorbed and disappeared, so that it had no permanent influence either on the life of the cell or the reproduction of young cells, though he recognised that it remained in the blood corpuscles of some animals. Henle, again, maintained that, as there are nuclei without nucleoli, so also cells exist without nuclei, and that new cells may arise without the least trace of cytoblasts.

At about the same time, and immediately after the publication of the important investigations by these eminent German observers, a young graduate of medicine of the University of Edinburgh, Dr Martin Barry, stimulated, he says, by the researches and encouraged by the friendship of Johannes Müller, Ehrenberg,

¹ *Allgemeine Anatomie*, Leipsic, 1841; also French translation by Jourdan in *Encyclopédie Anatomique*, vols. vi., vii., Paris, 1843.

Rudolph Wagner, and Schwann, undertook elaborate researches into the structure of the ovum, more especially in mammals. His results were published in a series of memoirs printed in the *Transactions of the Royal Society of London* from 1838 to 1841.¹ In these embryological memoirs, Barry announced several important discoveries. In his first memoir (1838) he pointed out that the germinal vesicle which had been discovered in the mammalian ovum by M. Coste and Mr Wharton Jones, was the first part of the ovum to be formed both in mammals and birds, and he thought that this was probably the case throughout the animal kingdom. In his second memoir (1839) he described the formation within the rabbit's ovum of the body which he named, and which has been known since his time as the mulberry-like structure. This body arose at first as two vesicles, then as four, and so on in multiple progression, so that Barry was the first to recognise in the ovum of mammals the process which we now know as the segmentation of the yolk. He showed that the vesicles of the mulberry body were cells, and that each contained a pellucid nucleus, and that each nucleus presented a nucleolus. Further, these vesicles arranged themselves as a layer within the zona pellucida.

Barry's third memoir was published in 1840, and as he gave it the subsidiary title of "A Contribution to the Physiology of Cells," it is clear that he regarded his embryological inquiries as having an important bearing on the facts of cell-formation and function. He repeated his observations on the formation of the mulberry-like body, and now recognised that its component cells had been derived from the germinal vesicle, the contents of which entered at first into the formation of two cells, each of which presented a nucleus which resolved itself into other cells, and by a repetition of this process, the cells within the ovum became greatly augmented in number. Further, he stated that the whole embryo at a subsequent period is composed of cells, filled with the foundations of other cells. Although we may not agree with all the details given by Barry in his account of these observations, yet there can be no doubt that he had early recognised the important fact, that in animals new cells arose within pre-existing cells, as Schleiden

¹ *Phil. Trans.*, vols. cxxviii.-cxxxii.

had affirmed to be the case in plants, and that the nucleus acted as an important centre for the production of young cells. In recognising the endogenous reproduction of young cells in animals, Barry made an important advance on the view entertained by Schwann, who regarded the endogenous production of cells as quite exceptional amongst animals.

In this same memoir Barry incidentally mentioned that he saw in the ovum of the rabbit a cleft or orifice in the zona pellucida, and that on one occasion he observed what he believed to be the head of a spermatozoon within the orifice. Two years afterwards he read to the Royal Society¹ a short paper, in which he announced that he had seen a number of spermatozoa within the ova of the rabbit, and in October 1843 he published a figure of an ovum with spermatozoa in its interior.²

In a memoir on the Corpuscles of the Blood, published in 1841, Barry announced a still more definite conception of the function of the nucleus. He directly traversed the statement of Schleiden, that the nucleus, after having given origin to the cell membrane, has performed its chief office, and is usually cast off and absorbed; as well as that of Schwann, who had never, except in some instances in fat cells, observed anything to be produced by the nucleus of the cell. Barry stated that the nucleus is a centre for the origin, "not only of the transitory contents of its own cell, but also of the two or three principal and last formed cells destined to succeed that cell; and in fact, that by far the greater portion of the nucleus, instead of existing anterior to the formation of the cell, arises within the cavity." Further, he says, "young cells originate through division of the nucleus of the parent cell, instead of arising as a sort of product of crystallisation in the fluid cytoblastema of the parent cell." He regarded the division of the nucleus in pus corpuscles as not artificially produced by the agency of acetic acid, as was held by Henle and Schwann, but as a part of the process by which cells were produced, and apparently universal in its operation.

In a paper published in 1847, Dr Barry summarised his observations on the nucleus of animal and vegetable cells, and

¹ *Phil. Trans.*, vol. cxxxiii.; read Dec. 8, 1842.

² "On Fissiparous Generation," *Edin. New Phil. Jour.*, Oct. 1843.

whilst expressing certain opinions on the mode of formation of the nucleolus and nucleus and the growth of cells which cannot now be accepted, he continued to maintain that cells are descended from an original mother-cell by cleavage of the nucleus, and all subsequent nuclei are propagated in the same way by fissiparous generation. Every nucleus, therefore, was a sort of centre, inheriting more or less the properties of the original nucleus of the fecundated ovum, which he conceived to be the germinal spot, and exercising an assimilative power. Dr Barry's contributions, therefore, to a correct conception of the development of cells, are of the highest importance when viewed in the light of modern observations.

But another Edinburgh inquirer, Mr John Goodsir, afterwards as Professor Goodsir, the distinguished occupant of the chair of anatomy in the University of Edinburgh, was engaged between the years 1842 and 1845 in studying the processes of cell-life, both in healthy tissues and in certain pathological conditions.¹ In his important memoir on *Secreting Structures*, published in 1842, he demonstrated from a variety of examples that secretion is a function of the nucleated cell, and he gave, as one of his many illustrations, the cells of the testis containing spermatozoa which were derived from the nuclei of these cells. In the original memoir he was inclined to believe that the cell wall was the structure engaged in forming the secretion; but in a reprint of it in 1845, he modified that view, and gave as his opinion that the secretion would appear to be a product of the nucleus. Goodsir also stated in the memoir of 1842 "that the nucleus is the reproductive organ of the cell, that it is from it, as from a germinal spot, that new cells are formed," and he cited cases in which it became developed into young cells. He subsequently, in a short paper on *Centres of Nutrition*, extended this view to the tissues generally. He defined the nutritive centres as minute cellular parts, existing, for a certain period at least, in all the tissues and organs.

¹ "On Secreting Structures," *Trans. Roy. Soc. Edin.*, 1842; "On Peyer's Glands," *London and Edinburgh Monthly Journal*, April 1842; "On Structure of Human Kidney," *ibid.*, May 1842; *Anatomical and Pathological Observations*, Edinburgh, 1845; also, his collected papers in *Anatomical Memoirs*, Edinburgh, 1868, edited by W. Turner.

They drew from the capillary vessels or other sources nutritive material, which they distributed to the tissues and organs to which they belonged. He regarded a nutritive centre as a cell, the nucleus of which is the permanent source of successive broods of young cells, which from time to time fill the cavity of their parent. He called this central or capital cell the mother of all those within its own territory or department. Goodsir also showed that cells were important agents in absorption, ulceration, and inflammation. In inflammation of cartilage, for example, he described and figured the cells in the area affected as increased in size, modified in shape, and crowded with a mass of nucleated cells in their interior, through the agency of which the walls of the corpuscles and the hyaline matrix became absorbed. He also gave illustrations of the multiplication of nuclei within cells in the course of formation of cysts. Corroborative observations on endogenous formation within animal cells were also given by Mr H. D. S. Goodsir, as confirmatory of the doctrine propounded by his brother on the cell as a centre of nutrition, secretion, and production of young cells. In a research into the structure of the testis in Decapodous Crustacea, Henry Goodsir observed that the head of the spermatozoon corresponded with the nucleus.

As regards the physiological action of cells, Mr (now Sir William) Bowman had expressed the opinion¹ that there was a strong presumption that the epithelium of glands assimilated the secretion from the blood. That the secretion might be separated, either by the passage of its elements through the cells; or by the cells undergoing solution or deliquescence; or by the cells being cast off entire with their contents. Mr (now Sir John) Simon also expressed, in 1845, some important general conclusions on the physiological action of cells.² He looked upon the cell wall as of secondary importance and of inessential formation, and he regarded the nucleus with the material developed around it as constituting the sole physical evidence of activity in the part. He saw bile and other secretions within cells, and stated that when the products of

¹ Article "Mucous Membrane," in Todd's *Cyclopædia*, date probably 1842 or 1843.

² *Essay on the Thymus Gland*, London, 1845.

secretion can be seen within a cell, they are accumulated in the portion which corresponds to the nucleus as though it were the true centre of attraction. Simon also observed the development of spermatozoa within cells, and had seen one end adhering to the relique of a cell, probably its nucleus.

The conception entertained both by Martin Barry and John Goodsir of the process of cell-formation and of the function of the nucleus was in the main very different from that propounded by Schleiden and Schwann. Whilst agreeing with Schleiden in holding that new cells were formed within parent cells, they did not look upon the process as one of deposition, in the first instance around a nucleolus and then around a nucleus, but they regarded the nucleus as the prime factor by the division of which new cells were formed.

With regard to the free formation of cells, as it was not unfrequently called, by deposition in a cytotblastema situated external to existing cells, to which Schwann and Henle attached so much importance in animals, they gave no concurrence. Both Barry and John Goodsir had grasped and advocated the fundamental principle, both of the endogenous development of cells from a parent centre and of an organic continuity between a mother cell and its descendants through the nucleus; and the brothers Goodsir had applied this principle in their anatomical, pathological, and zoological researches.

But histologists elsewhere had made isolated observations on the development in the animal body of young cells within parent cells. Even before the publication of Schwann's immortal treatise, Turpin had stated that the corpuscles which he found in vaginal discharges contained a new generation in their interior, and Dumortier had described secondary cells as formed in the ova of snails. These observations exercised, however, no influence on the progress of thought; and Schwann, though referring to them in the preface to his treatise, yet appeared to question their accuracy.

In 1841, Robert Remak published¹ an account of what he saw in the blood corpuscles of the chick, some of which were biscuit-shaped. At each end was a nucleus, and the two nuclei

¹ *Medicinische Zeitung*, p. 127, July 7, 1841.

were connected together by a thin stalk which traversed the intermediate part of the corpuscle. He thought it probable from these observations that a multiplication of blood corpuscles through division occurred. He obtained also similar evidence in the blood of the embryo pig, and saw both in the blood of the horse and of man red blood-cells formed in the interior of large mother cells. It is customary in Germany to credit Remak with being the first to recognise the division of the nucleus within the cell as a stage antecedent to, and associated with, the division of the cell itself; but from what has already been stated, it will be seen that Martin Barry had preceded him by some months¹ in the recognition of the importance of division of the nucleus in the production of young cells.

In 1843, Albert von Kölliker published² an interesting memoir on the changes which take place in the fertilised ova of various parasitic worms. He described and figured the production in regular progression of young cells within the ovum, and observed that in some cells the nucleus was elongated; in others constricted in the middle, as if about to divide; in others two nuclei were present, each smaller than the single nucleus of adjoining cells, as if they had arisen from the division of a larger nucleus. A legitimate inference from these observations was that in the formation of young cells, the nucleus of the parent cell divided into two, and that each of these gave origin to a new cell.

Observations on the endogenous multiplication of animal cells by division of the nucleus now began to be more widely recognised. It was described by Kölliker and by Mr (now Sir James) Paget in the embryo blood corpuscles, by Kölliker in

¹ Barry's later memoirs were read to the Royal Society of London, May 7, 1840; January 7, 1841; June 17 and 23, 1841. They are illustrated with numerous beautiful figures, in which the division of the nucleus and the endogenous production of young cells are shown. Further, it should be kept in mind that Remak's observation was on a single tissue, the embryonic blood corpuscle; whilst Barry's was a generalisation based on a large series of researches on the ovum, blood and mucous corpuscles, epithelium and other cells. John Goodsir, in a footnote to his important paper "On Centres of Nutrition," already referred to in text, p. 263, says—"For the first consistent account of the development of cells from a parent centre, and more especially of the appearance of new centres within the original sphere, we are indebted to the researches of Dr Martin Barry."

² *Müller's Archiv*, 1843.

cartilage and in the giant cells of the marrow of bones, and by various observers in the fertilised ovum. It acquired, therefore, much more importance as a mode of origin of animal cells than was accorded to it by Schwann.

At the time when I began the study of anatomy and physiology in 1850, the current teaching of the schools embraced two methods of cell formation,—the one through the intermediation of existing cells, which might be either by endogenous production within a mother cell through division of the nucleus, or by fissiparous division, or by budding off of a part of a cell; the other by a process of free cell-formation outside existing cells and within a blastema. When I came to Edinburgh in 1854 to act as demonstrator of anatomy, I found that the biologists were divided into two hostile forces,—the one was presided over by Professor John Goodsir, whose views on the intracellular origin of new cells I have already explained, and which he systematically expounded in his lectures; the other was led by the then Professor of the Institutes of Medicine, Dr Hughes Bennett. Dr Bennett, whose investigations into cell-formation and cell-life had been largely based, like those of Henle, on the study of pathological processes, was led to attach great importance to the granules or molecules which abound in the so-called inflammatory exudations and in purulent fluids. Bennett held that molecules arose in an organic fluid, and that an aggregation of molecules produced nuclei, upon which cell-walls may be formed; that the molecule was the primary, elementary and most simple form of organised matter, and that an aggregation of molecules might even form fibres and membranes without the agency of cells. His views were almost a reproduction of those of Henle, and he advocated them with great vigour and persistency, especially in regard to the production of pus and other products of inflammation.

Pathologists had indeed very generally supported the theory of the free formation of cells in exudations; but this view, however, was not universally entertained by them. Professor Goodsir¹ and Dr Redfern² had shown its inapplicability in

¹ *Opera citata.*

² "Abnormal Nutrition in Articular Cartilages," *Edinburgh Monthly Medical Journal*, August 1840; and separate *Memoir*, Edinburgh, 1850.

inflammation and ulceration of articular cartilages. Professor Virchow, in a series of papers in his *Archiv*, commencing with vol. i. in 1847, had described the endogenous formation of young cells in pathological structures. In his lectures on Cellular Pathology, published in 1858, Virchow, like Goodsir, announced his belief in the mapping out of the body into cell territories. Virchow's conception of the territory was the intercellular substance immediately surrounding a cell, and subject to its influence.¹ He maintained that in pathological structures there was no instance of development *de novo*, but that where a cell existed, there one must have been before. He called it the law of continuous development, which could be formulated in the expression *omnis cellula e cellula*. He adduced a great variety of specific instances to show the diffusion throughout the tissues and organs of nucleated cells, and he established, by a variety of proofs, the important part played by the cell elements, more especially those of the connective tissue, in the inflammatory process and in the production of new formations. He advanced, indeed, such a mass of evidence in support of this position, that the theory of free cell formation was shortly after abandoned in connection with pathological processes, as it had been some time previously by most observers in normal histiogenesis.²

The continued investigations into the structure of cells, both in plants and animals, led to modifications in the conception of their morphology. Hugo von Mohl announced that he had discovered³ in the vegetable cell, after being acted on by alcohol and iodine, a thin nitrogenous membrane distinct from and applied to the inner surface of the cellulose wall of the cell, which he named the *primordial utricle*. He regarded it as forming a vesicle within the cell wall, and containing the contents and the nucleus. By subsequent observers it has been shown that the primordial utricle is nothing more than a thin

¹ He first used the term Zellen Territorien in his *Archiv*, Bd. iv., 1852, p. 383.

² In a Lecture which I delivered before the Royal College of Surgeons, Edinburgh, in 1863 (*Edinburgh Medical Journal*, April 1863), I summarised the evidence of the derivation of pathological cell formations from pre-existing cells, and adduced additional examples from my own observations.

³ *Botanische Zeitung*, translated by A. Henfrey in Taylor's *Scientific Memoirs*, vol. iv., 1846.

layer of protoplasm lying close to the cellulose wall, and enclosing the sap cavity of the cell.

Professor Huxley, in an article on the Cell Theory,¹ criticised the views of Schleiden and Schwann, and introduced the terms *endoplast* and *periplast* into histological description. He regarded the primordial utricle as the essential part of the endoplast in the plant, and as homologous with the "nucleus" of the animal cell; whilst the protoplasm and nucleus were simply its subordinate modifications. The periplast, on the other hand, consisted in plants of the cellulose cell wall; whilst in animals the cell wall and matrix of cartilage, the cell walls and intercellular substance of connective tissue, the calcified matrix of bone, and the sarcous elements of muscular fibre were all examples of periplast which had passed through various forms of chemical and morphological differentiation. Huxley maintained that the periplast was the metamorphic element of the tissues, and by its differentiation every variety of tissue was produced, owing to intimate molecular changes in its own substance. The endoplast again might grow and divide, as in the process of cell multiplication; but it frequently disappeared and underwent neither chemical nor morphological metamorphosis; and so far from being a centre of vital activity, he held that it exercised no attractive, metamorphic, or metabolic force upon the periplast.

But about this time it began to be more distinctly recognised that many anatomical units which were to be regarded as cells, as Schwann had indeed admitted in a few exceptional cases, possessed no cell wall or investing membrane, and that the analogy with a bladder or vesicle could no longer be sustained. Thus in 1856,² Leydig gave as his idea of a cell a more or less soft substance, approaching in its original state to the globular in form, which enclosed a central body, the nucleus. Subsequently, the cell substance might harden into a more or less independent membrane, and the cell would then consist of membrane, contents, and nucleus. Leydig's conception therefore of what were the essential parts of a cell closely corresponded with the opinion expressed some years previously

¹ *British and Foreign Medico-Chirurgical Review*, Oct. 1853.

² *Lehrbuch der Histologie*, 1857. Preface dated October 1856.

by John Simon. Brücke again maintained¹ that the constancy of the presence of a nucleus was subject to certain limitations, especially in the cells of cryptogams, and that there was no positive information either respecting the origin or the function of the nucleus. He further showed that the soft contents of the cell were of a highly complicated nature, and that they frequently exhibited spontaneous movements and contractility. In 1861 and also in 1863, Max Schultze published² most important papers on the properties of cells. He adopted the term protoplasm which Von Mohl had employed to designate the contents in vegetable cells which surround the nucleus, and applied it to the substance which had the corresponding position in animal cells. He completely discarded the view that a membrane was essential to a cell, and defined a cell as a nucleated mass of protoplasm. He identified the protoplasm of the animal and vegetable cell as essentially the same substance as the contractile sarcode which forms the freely moving pseudopodia of the Rhizopoda, and he looked upon it as possessing great physiological activity. The conception of the functions and relative importance of the constituent parts of a cell had now undergone a material change. The suggestive ideas of Simon and Leydig had now been distinctly formulated by Max Schultze. Instead of the cell membrane being regarded as a necessary part of a cell, and the active element concerned in the formation of the cell contents, as Schwann believed, it now became universally recognised as only a secondary structure formed by a differentiation of the superficial part of the protoplasm. Schultze also maintained that the appearance of the membrane might be looked upon as a sign of commencing loss of activity, for a cell with a membrane can no longer divide as a whole, but the division is restricted to the protoplasm contained within it. A cell with a membrane is, he says, like an encysted Infusorian. Taking the embryonal cell as a type, he believed that both the nucleus and the protoplasm were derived from the corresponding constituents of another cell. The protoplasm was the substance especially endowed with living force; the nucleus, he thought, played an

¹ "Elementar Organismen," *Wien Sitzbericht*, 1861.

² *Müller's Archiv*, 1861, p. 1; *Das Protoplasma*, Leipzig, 1863.

important rôle, though its exact function could not be defined. The only structural character which Schultze recognised in the protoplasm, was a finely granular appearance throughout the somewhat jelly-like, contractile material in which the granules were embedded. Although the name of protoplasm was now given to this substance, yet it obviously corresponded morphologically with the blastema which both Schleiden and Schwann had recognised within the cell, between the nucleus and the cell wall; though it now assumed in the minds of observers a different physiological import.

The reign of protoplasm had now been inaugurated. Not only was the cell membrane believed to be a product of its differentiation, but the matrix of cartilage and of connective tissues, and the other intercellular substances, were thought to be produced not as a secretion, but by a conversion of the protoplasm of the cells into their respective forms. But, further, Max Schultze¹ described a non-nucleated *Amœba*; and Haeckel² and Cienkowski³ other non-nucleated organisms, simple in their structure. These organisms were believed to consist solely of a clump of soft protoplasm, which might either be naked, when they were called *simple cytodes*; or encased in a wall or envelope, and then termed *encased cytodes*. Haeckel named these—the most simple of all organisms—*Monera*, and referred them to a group on the confines of both the animal and the vegetable kingdoms, which he termed *Protistæ*. Stricker⁴ also excluded the nucleus as necessary to our conception of an elementary organism. He went so far as to say that the historic name of cell might be applied to the morphological elements of the higher animals, or to independent living organisms, even if they were only little masses of animal sarcode or protoplasm. He was not, however, disposed to extend the definition to isolated fragments of living protoplasm, unless the whole group of phenomena characteristic of an independent organism could be recognised. Stricker held that protoplasm may be fluid, solid, or gelatinous. It exhibited the phenomena of movement, of

¹ *Organis. de Polyth.*, 1854.

² *Zeitsch. f. wiss. Zool.*, 1865, Bd. xv.

³ Max Schultze, *Archiv*, 1865.

⁴ "Allgemeines über die Zelle," in *Handbuch der Lehre von den Geweben*. Leipzig, 1871.

nutrition, of growth, and the capability of reproducing its like, *i.e.*, the sum of the phenomena which are characteristic of living organisms.

The doctrine that a nucleated mass of protoplasm was the structural unit common to organisms generally, both plants and animals, though at the very bottom of the scale the phenomena of life could be manifested by a particle of protoplasm without a nucleus, received its most popular expression in this country at least, in a well-known Address by Professor Huxley.¹ In this address he stated that protoplasm, simple or nucleated, is the formal basis of all life, and that all living forms are fundamentally of one character. His views, therefore, had undergone some modification since the publication of his previous article on the Cell Theory.

But contemporaneous with these researches on the protoplasmic theory of cell structure and activity, an English physiologist, Dr Lionel Beale, was conducting investigations into the structure of the simple tissues from an independent and somewhat different point of view. He considered that the elementary tissues of every living being consisted of matter in two states,²—the one an active, living, growing substance, composed of spherical particles, capable of multiplying itself, and coloured red by carmine, which he named *germinal matter*; the other, named by him *formed material*, was situated peripherally to the germinal matter from which it was produced; it was passive, non-living or dead, incapable of multiplying itself, and not coloured red by carmine like the germinal matter. In adapting these terms to the ordinary nomenclature of the cell, Dr Beale states—

In some cases the germinal matter corresponds to the "nucleus"; in others to the "nucleus and cell contents"; in others to the matter lying between the "cell wall," and certain of the "cell contents": while the formed material in some cases corresponds exactly to the "cell wall" only; in others to the "cell wall and part of the cell contents"; in others, to the "intercellular substance"; and in other instances to the fluid or viscid material which separate the several "cells, nuclei, or corpuscles" from each other.

¹ "On the Physical Basis of Life," a Lay Sermon delivered Nov. 8, 1868; *Fortnightly Review*, and Lay Sermons and Addresses, London, 1870.

² *Structure of the Simple Tissues*, London, 1861.

According to this theory of the tissues, all the elementary parts of the body consist of two substances—an active, living, germinal matter, and an inactive, non-living, formed material. Every living elementary part is derived from a pre-existing living elementary particle. The nuclei of the germinal matter, though remaining for a long time perhaps in a comparatively quiescent state, may become active and give rise to new nuclei. Dr Beale held that the cell wall was by no means constantly present in cells, and that when present, both it and the intercellular substance were formed or produced by, or a conversion of the germinal matter. In a subsequent work, Beale¹ substituted the term *bioplasm* for germinal matter, and included in it the nucleus, nucleolus, and some forms of protoplasm. It is from the bioplasm that the formed material is produced.

An important advance was made in the conception of the structure of the constituent parts of the cell when it was ascertained that protoplasm was not the structureless, granulated jelly, or slime, which it was originally supposed to be, but that it consisted of two parts, viz., a minute network of very delicate fibrils and an apparently homogeneous substance which occupied the interstices of the network. Stilling and Max Schultze recognised the fibrillated character of the protoplasm of nerve cells and axial cylinders, but Frommann, Heitzmann, Klein, and other histologists applied the observations to the structure of protoplasm generally.

The subject made a yet greater step forwards when it was ascertained by Strasburger and Flemming that the nucleus in its passive or resting stage consists, in addition to the nucleolus, of threads or fibres, some finer, others coarser, formed of *nuclein*, and arranged in a reticular network, so as to form little knots at the points of intersection of the fibres. In the interstices of the network an apparently structureless intermediate substance, nuclear fluid or *nucleoplasm*, is situated; and the nucleus is surrounded by a membrane.² By some observers the threads are regarded not as forming a network, but as a greatly coiled single thread. From the affinity which they have for colouring

¹ *Bioplasm*, London, 1872.

² This membrane is perhaps nothing more than a somewhat differentiated layer of the protoplasm of the cell arranged around the nucleus.

matter so that they easily stain with dye, Flemming has named them *chromatin fibres*.¹ But the whole question of the relation of the nucleus to the life of the cell, more especially in connection with the production of young cells, assumed a much more definite form when it was discovered that the chromatin nuclear fibres took a primary part in the division of the nucleus in the process of cell multiplication, and the nucleus was re-instated in its place as of primary importance in the structure of cells, and as an essential factor in the formation of new cells. The movements of the fibres within the nucleus, and their rearrangement so as to form definite figures, which changes precede the act of division, were named by Schleicher *karyokinesis*, or nuclear movement, a term which has now been generally adopted.²

Waldeyer states that Schneider of Breslau was the first to recognise these movements of the nuclear fibres, and to describe them in connection with the division of the ova, the sperm cells, and also the tissue cells of a flat worm, *Mesostomum*; but Bütschli and Fol made the process more generally known. The publication of their researches excited the greatest interest, and a host of observers, amongst whom I may especially name Strasburger, Flemming, E. van Beneden, Johow, Heuser, Pfitzner, J. M. Macfarlane, Hertwig, Balbiani, Carnoy, and Rabl, demonstrated the process in a number of plants and animals, and the literature of the subject is now very extensive. In order to express the appearances presented, and the changes which take place both in the nucleus and in the cell in the process of division, a new nomenclature has been introduced, and we now read of cytaster, monaster, dyaster, equatorial plate and crown, pithode or cask-shaped, spindles, ellipsoids, coils, skeins both compact and loose, pole radiations, spirem, and other terms. From the range of the literature it would be a work of considerable labour and time to make an analysis of the different observations so as to associate with the name of each observer

¹ The chromatin fibres appear to be composed of granules or spherules, named "microsome-discs" by Strasburger.

² Flemming proposed the term *Karyomitosis*, or nuclear threads, to express the thread-like figures formed in the process. M. Carnoy gives the name *enchyloema* to the apparently structureless material which occupies the interstices of the network both of the nucleus and cell protoplasm.

the particular set of facts or opinions which he has made known. Fortunately, this is unnecessary on my part, as admirable resumés of the whole subject have recently been published both by Professor M'Kendrick of Glasgow¹ and Professor Waldeyer of Berlin.²

Without entering into a detailed description, it may suffice my present purpose to say that four stages may be recognised in connection with nuclear division.

The *first*, or *spirem stage*, exhibits several phases. At its commencement the finer threads, which connect the primary or coarser chromatin fibres of the resting nucleus together, and which give the network-like character, have disappeared along with the knots at their points of intersection and the nucleoli. The primary chromatin fibres, or *chromosome* as Waldeyer calls them, form a complex coil, the spirem or ball of thread, which divides into loops, about twenty in number, and forms a compact skein. The loops are placed with their apices around a clear space called by Rabl the "polar field," whilst their free ends reach the opposite surface of the nucleus or "antipole." The nucleus also increases in size coterminously. The loops next become not so tightly coiled, and form the loose skein, though the individual fibres thicken and shorten. A most important change then occurs, which was discovered by Flemming, and which consists in a longitudinal splitting of each loop or primary chromatin fibre into two daughter threads. A spindle-shaped figure, first seen by Kowalevsky, next appears in the nucleus, which consists of threads that stain much more feebly than the chromatin fibres.³ The spindle has two poles and an equator, and it finally occupies a position in the deeper part of the nucleus; its equator lies in the plane, through which division of the nucleus is about to occur. The loops of chromatin fibres group themselves in a ring-like manner around the equator (described by Fol and Schneider) of the spindle with their angles inwards, whilst from each pole of the spindle a radiated appearance (*cytaster*) extends into the protoplasm of the cell. The membrane of the nucleus has now disappeared,

¹ *Proc. Phil. Soc.*, vol. xix., Glasgow, 1888.

² *Archiv für Mikros. Anat.*, Bd. xxxii., 1888.

³ Owing to the feeble staining of the spindle figure and of the nucleoplasm, the substances which compose them have been named *Achromatin*.

so that it is directly invested by the protoplasm of the cell; and it is possible, as Strasburger thinks, that there may be a direct flow of the protoplasm into the nucleus, and that the spindle may be produced by it. At the pole of the spindle, from the point at which the cytaster radiates, E. van Beneden has seen a small, shining, polar body, which Strasburger says is not found in vegetable cells.

The *second*, or *monaster stage*. When the chromatin loops have arranged themselves about the equatorial plane of the spindle with their limbs pointing outwards, and the angle of the loop towards the centre of the spindle, a single star-like figure (*monaster, equatorial plate* or *crown*) is produced. The two daughter threads into which each primary chromatin thread had previously split longitudinally, now separate from each other, and, according to Van Beneden and Heuser, pass to opposite poles of the nuclear spindle, where they form loops. These changes are known as the process of *metakinesis*.

In the *third*, or *dyaster stage*, the chromatin loops at each pole of the spindle arrange themselves so that the angles of the loops, though not touching each other, are close together at the pole, and the limbs of the loops are bent towards the equator of the spindle. Two stars are thus produced (*dyaster*), one at each pole, and each star is formed of one of the daughter threads into which each chromatin fibre of the monaster divides by its longitudinal splitting. Each star is sometimes called a daughter skein; around each daughter skein a membrane appears at this stage, and a daughter nucleus is then formed.

In the *fourth*, or *dispirem stage*, the chromatin threads thicken and shorten, and the loops arrange themselves with the angles towards the polar field of the nucleus, and the limbs to the anti-pole.

The division of the mother cell into two new daughter cells is now completed by the cell protoplasm gradually constricting in the equatorial plane until at last it is cleft in twain, and each daughter nucleus is invested by its own mass of protoplasm. The chromatin threads of the daughter skein then form a network of coarser and finer fibres, a nucleolus appears, and the resting nucleus of the daughter cell is completed. Two daughter cells have thus arisen, each of which possesses its own

independent vitality. Owing to the very remarkable longitudinal splitting of the fibres of the chromosome, and the distribution of the daughter threads from each fibre to the opposite poles of the spindle, it follows that each daughter nucleus contains about one-half of each chromatin fibre, so that whatever be the properties of the chromosome of the mother cell, they are distributed almost equally between the nuclei of the two daughter cells. As regards the cleavage of the protoplasm, there is no evidence that such a rearrangement of its constituent parts takes place as to give to each daughter cell one-half of the protoplasm from each pole of the mother cell. It is probable that each daughter nucleus simply becomes invested by that portion of protoplasm which lies in proximity to it at the time when the constriction of the protoplasm begins. The young daughter cell, seeing that it is composed both in its nucleus and protoplasm of a portion of each of these constituent parts of the mother cell, possesses therefore properties derived from them both.¹

Owing to the disappearance of the nuclear membrane at the end of the spirem stage of karyokinesis, at least in cells generally (though it is said to persist in the Protozoa during the whole process of karyokinesis), it follows that the nucleoplasma and the cell protoplasm cease for a time to be separated from each other, and an interchange of material may take place between them in opposite directions—both from the protoplasm to the nucleus, as Strasburger contends, and from the nucleus to the protoplasm, as has in addition been urged by M. Carnoy. In every case it should be remembered that the nucleus, being surrounded by protoplasm, can only obtain its nutrition through the intermediation of that substance, and thus there is always a possibility of the protoplasm acting on the nucleus, and in so far modifying it.

Having now sketched the progress of knowledge of the structure of cells and their mode of production, I may, in the next instance, state the present position of the subject. We have

¹ Dr J. M. Macfarlane has described as constantly present within the nucleolus of vegetable cells a minute body, which he terms *nucleolo-nucleus* or *endonucleolus*. He considers it as well as the nucleolus to become constricted and divided before the nucleus and the cell pass from the resting into the active phase of cell multiplication. See *Trans. Bot. Soc. Edin.*, 1880, vol. xiv., and *Trans. Roy. Soc. Edin.*, 1881-82, vol. xxx.

seen that the original conception of a cell was a minute, microscopic box, chamber, bladder, or vesicle, with a definite wall, and with more or less fluid contents. This conception was primarily based upon the study of the structure of vegetable tissue; and, as regards that tissue, it holds good to a large extent to the present day. For the cellulose walls of the cells of plants, with their various modifications in thickness, markings, and chemical composition, constitute the most obvious structures to be seen in the microscopic examination of vegetable tissue. Within these chambers is situated the active, moving protoplasm of the cell, and embedded in it is the nucleus; it also contains the sap, crystals, starch granules, or other secondary products. The cell wall is to all appearance produced by a conversion of or secretion from the protoplasm. But even in plants a cell wall is not of necessity always present; for, in the development of the daughter cells within a pollen mother cell, there is a stage in which the daughter cell consists only of a nucleated mass of protoplasm, prior to the formation of a cell wall around it by the differentiation of the peripheral part of its protoplasm. Again, the so-called non-cellular plants or Myxomycetes, before they develop their spores,¹ consist of masses of naked protoplasm, on the exterior of which, in the course of time, a membrane or cell wall is differentiated. In the substance of these masses of protoplasm numerous nuclei are situated.²

In animal tissues the fat cell possesses a characteristic vesicular form, with a definite cell wall, but neither in it nor in the vegetable cells does the cell wall exercise any influence on the secretion either of cell contents or of matters that are to be excreted. In animal cells a cell wall is frequently either non-existent, or doubtful, and when present is a membrane of extreme thinness. Animal cells, therefore, do not have as a rule the chamber-like form or vesicular character of vegetable cells.

The other constituents of the cell, and the only essential constituents, are the nucleus and the material immediately surrounding it in which the nucleus is imbedded. It is of secondary

¹ *Lectures on the Physiology of Plants*, by Julius von Sachs. Translated by H. Marshall Ward, Oxford, 1887.

² The opinion for long entertained that the simpler algae and fungi and cryptogams generally are destitute of nuclei has been shown by Schmidt and others to be incorrect.

importance whether this material be called protoplasm, or bioplasm, or germinal matter. The term protoplasm, however, is that which has received most acceptance. In adopting this term, it should be employed in a definite sense to express the translucent, viscid, or slimy material, dimly granular under the lower powers, minutely fibrillated under the highest powers of the microscope, which moves by contracting and expanding, and which possesses a highly complex chemical constitution. The term ought not to embrace either the cell wall of the vegetable or animal cell, or the intercellular substance of the animal tissues. For although these have in all probability been originally derived from the protoplasm, by a chemical and morphological differentiation of its substance, they have assumed formal and specific characters and have acquired distinct functions. Protoplasm, as above defined, is a living substance endowed with great functional activity. It possesses a power of assimilation, and can extract from the appropriate pabulum the material that is necessary for nutrition, secretion, and growth. Growth takes place not by mere accretion of particles on the surface, but by an interstitial appropriation of new matter. In cases, also, where the media in which the cell lives are suitable, as in the freely moving *Amœba*, or the white blood corpuscles, portions of the protoplasm may separate by budding from the general mass of the cell, and assume an independent existence; but the conditions under which the budding off of protoplasm can take place are exceptional in the higher organisms. Protoplasm, therefore, according to this definition, in addition to being a moving contractile substance, is the nutritive and secreting structural element of the tissues, and is always found relatively abundant where growth and the nutritive processes are most active.

In the fertilised ovum, after the process of segmentation has begun, and in the earlier stages of development of the embryo, the cells are nucleated masses of protoplasm, without cell walls, and with no intercellular material. In the course of time, in animals more especially, an intercellular substance arises apparently by a differentiation of, or secretion from the protoplasm. In many of the tissues this substance acquires such characters, magnitude, and importance as to overshadow the nucleated masses of protoplasm which it lies between and surrounds.

The intercellular substance is the principal representative of the "formed material" of Dr Beale. I cannot, however, agree with him in regarding it as passive and non-living or dead; for morphological and functional changes take place in it long after its original formation. Thus the hyaline matrix, or intercellular substance, of the young costal cartilages becomes converted into a fibrous matrix in the later period of life, and the striated substance of muscular fibre is one of the most physiologically active tissues in the animal body. In the general economy of the tissues, in the fitting of each to discharge the function for which it is specially intended, the intercellular substance plays an essential part. It gives strength to the bones, toughness and elasticity to ligaments and cartilage, motor power to muscles. It wastes by use and needs repair. But it is probably to the nucleated protoplasm within its substance that we are to look for the structural element which attracts to it the pabulum required for its nutrition, so that the interstitial waste which is consequent on its use may be made good.

The nucleus is also an active constituent of the cell. It is doubtful if it plays a part as a centre of attraction in secretion, or in the nutrition of the cell generally, an office which is most probably discharged by the protoplasm; but it undoubtedly acts as a centre for its own nutrition. Numerous observations, however, clearly prove the truth of the generalisation originally propounded by Martin Barry, and confirmed by Goodsir, that the nucleus is intimately associated with the production of young cells. The karyokinetic phenomena which have been observed during the last fifteen years have established this on a firm basis, beginning with the original segmentation within the ovum down to the latest period of cell formation.

But, along with the karyokinetic changes within the nucleus and its cleavage, there is also a cleavage of the protoplasm of the cell, so that the daughter cell consists of portions of both the nucleus and the protoplasm of the mother cell. The question therefore has been put whether the division of the protoplasm is a consequence or a coincidence of the division of the nucleus. I am inclined to think that the cleavage of the cell protoplasm is consequent on the nuclear changes; for it must be kept in mind that certain of the movements in and rearrangement of

the chromatin fibres of the nucleus precede any rearrangement of particles in the cell protoplasm so far as yet observed, and, still more, the process of cleavage. Applying, therefore, to the cell the well-known economic principle of division of labour, and that differentiation of structure carries with it differentiation of function, I regard the protoplasm as the nutritive and secreting element of the cell, and the nucleus as its primary reproductive factor.

The present position of the CELL THEORY differs therefore in many important respects from the doctrine advocated by Schwann and his immediate successors. Cells are no longer regarded as of necessity bladders or vesicles. A cell wall is not constant but of secondary formation. A free formation of cells within an extracellular blastema by deposition around a nucleolus to form a nucleus, and then around the nucleus to form a cell, does not take place. Young cells arise from a parent cell by division of the nucleus, followed by cleavage of the cell protoplasm. Although in so many of its details, therefore, the theory of Schwann has been departed from, yet the great generalisation of the cellular structure of plants and animals holds good, and his work will continue to mark an epoch in the progress of biological science.

The study of the very remarkable series of karyokinetic phenomena described in an earlier part of this address has given an impulse to speculation and thought in connection with some of the most abstruse problems of Life and Organisation. The question of the hereditary transmission of properties, both as regards the constituent tissues of the organism and the individual as a whole, has been put on a more definite physical basis. The discovery by Martin Barry of the penetration of the ovum by the spermatozoon has been completed by the researches of Bütschli, Fol, E. van Beneden, and Hertwig. The conjugation of the male pronucleus or head of the spermatozoon with the female pronucleus derived from the germinal vesicle, and the consequent formation of the segmentation nucleus, has been demonstrated. The segmentation nucleus is built up of chromatin fibres and nucleoplasm, derived from both the nucleus of the male sperm cell or spermatozoon and the nucleus of the female germ cell. It is therefore a composite nucleus, and represents both parents. The cells derived from the segmentation nucleus

in the early stage of segmentation contain chromatin nuclear particles which are in direct descent from the chromatin fibres of the segmentation nucleus, and through it from the corresponding fibres of both the sperm and germ cells. The segmentation cells then arrange themselves to form the blastoderm, which, in the more complex organisms, by the continuous subdivision of the cells, forms three layers; from which, by a prolonged process of cell division and differentiation, all the tissues and organs of the adult body are ultimately derived. Karyokinetic changes mark the process of cell division throughout, and each daughter cell receives from the mother cell chromatin nuclear material derived from both parents, which, without doubt, convey properties as well as structure.

In the division of the segmentation nucleus within the ovum a cleavage of the protoplasm of the egg also takes place, and each daughter nucleus is enveloped by the protoplasm of the maternal egg. If during the period of nuclear division there is no interchange of matter between the nucleus and the protoplasm which incloses it, the cell protoplasm would then be derived solely from the ovum, and would represent maternal characters only, whilst the nucleus would possess characters derived from both parents. But if, as is most likely, during the process of karyokinesis, when the nuclear membrane has disappeared, an interchange of matter takes place between the nuclear substance and the cell protoplasm, the latter would then become, if I may say so, inoculated with some at least of the nuclear substance, and be no longer exclusively of maternal origin. Should this be so, the whole of the cells of the body and the tissues derived from them would, as regards both nucleus and cell protoplasm, be descended from material originally belonging to both parents.

Although ova in different organisms differ materially from each other in size, shape, the relative amount of food-yolk which they contain, the mode of segmentation, and the presence or absence of a segmentation cavity, they all agree in this that the primordial cells of the egg are nucleated masses of protoplasm. Notwithstanding, the general resemblance of the morphological units which thus mark the first stage in the production of young organisms, each fertilised ovum gives rise to

an organism resembling that in which the egg itself arose. Hence the offspring resemble the parents, and the species is perpetuated by hereditary transmission, so long as individuals remain to keep up the reproductive process. During sexual reproduction the substance of the segmentation nucleus undergoes karyokinetic changes during the act of segmentation, and the question arises if the process of karyokinesis is the same for all organisms, whether plants or animals, or if there are specific differences. As the fertilised ovum is potentially the organism which is to arise from it, specific differences not unlikely exist in the minute structure of the segmentation nucleus, which might be expressed by modifications in the arrangement of the chromatin fibres and in the number of their loops. The varieties which have been described in the forms of the karyokinetic figures and polar radiations in different plants and animals may perhaps mark these specific differences.

But there is another question which merits consideration. Are the karyokinetic phenomena which show themselves in the cells of a given tissue characteristic of that tissue; and, if so, would it be possible to distinguish one tissue from another in the same organism by differences in the process of cell division? On this point a commencement seems to have been made towards obtaining some positive knowledge. Strasburger and Heuser think that they have obtained evidence in certain plant cells that such is the case; Rabl concludes, from observations on the epidermic cells of Salamander, that the loops of chromatin fibres are constantly twenty-four in number in the same kind of cell in the same species of animal.

But in considering the different kinds of tissue, and the possibility of each kind possessing its characteristic karyokinetic process, it has to be kept in mind that more than one kind of tissue, each of which has its characteristic structure and function, arises from each layer of the blastoderm, so that there is a stage in development—a stage of indifferentism, if I may use the expression—when the blastoderm represents several tissues which have not yet differentiated. From the epiblast, for example, tissues so diverse in structure and function as cuticle and nerve tissue arise. Now, if there be a special karyokinetic process for the epidermal cells, and another for the nerve cells, does either

of these correspond with the process of nuclear division in the cells of the epiblast in their stage of indifferentism, or do they both differ from it? When does the impulse reach the layers of the blastoderm, so as to produce in their constituent cells changes which so alter the characters of the cells as to lead to a differentiation into various forms of tissues, and to what is that impulse due? In the development of each species there seems to be a definite time within certain limits when the differentiation shall begin, and when the process of development of the tissues and organs shall be completed. This is a hereditary property, and is transmitted from parents to offspring. Is the impulse derived from the nucleus or from the cell protoplasm, or do both participate? As already stated, the nucleus is the element which is immediately descended from both parents, and which may therefore be supposed to be the primary, morphological unit through which hereditary qualities are transmitted. But, as is most probable, the nucleus reacts on the cell protoplasm—on the element of the cell through which the ordinary nutritive functions are discharged. As a consequence of this reaction when the appropriate time arrives in the development of each species, for the commencement of the differentiation of the protoplasm of a cell, or group of cells, into a particular kind of tissue, the necessary morphological, chemical, and physiological changes take place. When once the differentiation has been effected, it is continued in the same tissue throughout the life of the organism, unless through some disturbance in nutrition, the tissue atrophies or degenerates. Every multicellular organism, in which definite tissues and organs are to arise in the course of development, has therefore a period, varying in its duration in different species, in which certain of the properties of the cells are as it were dormant. But, under the influence of the potent factor of heredity, they are ready to assume an active shape as soon as the proper time arrives. When the process of differentiation and development is at an end, the organism has attained both its complete individuality as regards other organisms, and its specific characters.

Every organism, therefore, has to be viewed from both these points of view. Its specific position is determined by that of its parents, and is due to the hereditary transmission of specific

characters through the segmentation nucleus. Its individuality is that which is characteristic of itself; and arises from the fact that in the course of development a measure of variability within the limits of a common species, from the organic form exhibited by its parents and their other offspring, is permitted. In all likelihood the variability, as Weismann has suggested,¹ is, to a large extent, occasioned by the bisexual mode of origin of so many organisms. Also to the possibility of the molecular particles of the segmentation nucleus and of the nuclei of the cells descended from it, having a method of arrangement and adjustment, and a molecular constitution characteristic of the individual as well as of the species. On this matter we have, however, no information. It is as yet a mere hypothesis. When we consider the extreme minuteness of the objects referred to, and recollect that it is only about fifteen years since karyokinetic phenomena were first recognised, it is astonishing what progress in knowledge has been made within this limited period. We owe this great advance to the much more complete magnifying and defining power of our microscopes, to the improved method of preparation of the objects, and to the acute vision and clear-thinking brains of those observers who have worked at the subject. By continuing the work, and extending it over a wider area, we may hope in time to be able to solve many questions to which we cannot now give an answer.

The nuclear material which makes up the substance of the male and female pronuclei, by the fusion of which the segmentation nucleus is formed, has been termed by Professor Weismann the *germ plasm*. In a series of elaborate papers he has developed a Theory of Heredity,² based upon the supposed continuity of the germ plasm. He believes that in each individual produced by sexual generation a portion of the germ plasm derived from both parents is not employed in the construction of the cells and tissues of the soma, or personal structure of that individual, but is set aside unchanged for the formation of the germ cells of the succeeding generation—that is, for reproduction

¹ See his Essay on the significance of sexual reproduction in the theory of Natural Selection; translated in *Essays on Heredity*, Oxford, 1889.

² Translations of these papers have been published by the Clarendon Press, Oxford, 1889.

and the perpetuation of the species. According to this theory, the germ plasm, more especially through the chromatin fibres, is the conveyer of hereditary structure and properties from generation to generation. Further, he holds that the cells, tissues, and organs, which make up the somatic or personal structure of the individual, exercise no modifying influence on the germ or reproductive cells situated in the body of that individual, which cells are also, he thinks, unaffected by the conditions, habits, and mode of life. In its fundamental idea Weismann's theory is in harmony with one propounded a few years earlier by Mr Francis Galton.¹

In an address which I delivered at Newcastle in September last to the Anthropological Section of the British Association,² I reviewed this theory of heredity, and, whilst finding in it much with which I could coincide, I directed attention to points to which, I thought, objection might be taken. More especially I took exception to the idea that the germ plasm was so isolated from the cells of the body generally as to be uninfluenced by them, and to be unaffected by its surroundings.

On this occasion I propose to say a few words on the bearing of this theory on the development of the tissues and organs of the individual. If we examine the development of the embryo, say of one of the Vertebrata, we find that it makes a certain advance, varying in its time and extent according to the species, without any differentiation of a reproductive organ with its contained germ plasm being discoverable. I shall not enter into the much-disputed question of the layer or layers of the blastoderm from which the reproductive cells take their rise. But I may say that in the Chick, both in the third and fourth day of incubation, a layer of germinal epithelium may be seen in close relation to the Wolfian duct and the pleuro-peritoneal cavity. At the end of the fourth day or in the fifth day this epithelium becomes thickened, and the primordial ova appear in it as distinctly differentiated cells. In the Rabbit a corresponding differentiation does not appear to take place

¹ *Proc. Roy. Soc. London*, 1872; and *Jour. Anthropol. Inst.*, vol. v., 1876.

² This address was reported at considerable length in the *Times* newspaper, September 14th, and in full in *Nature*, September 26th. It will also appear in the reports of the Newcastle meeting published by the Association.

before the twelfth or thirteenth day. Up to the period of differentiation of the primordial ova, no isolation or separation of the reproductive cells and germ plasma has taken place; and so far as observation teaches there is nothing to enable one to say which cells of the blastoderm may give rise to primordial ova, or which may differentiate into cells for other histiogenetic purposes. But before the germ cells appear, the rudiments of the nervous, vascular, skeletal, muscular, tegumentary, and alimentary systems, and the Wolffian bodies or primordial kidneys have all been mapped out. Up to this time, therefore, in all probability, a more or less complete diffusion of the germ plasma throughout either one or more of the layers of the blastoderm has taken place. In this way one might account for the hereditary influence carried by the germ plasma being brought to bear upon the cells of the blastoderm generally, so as to impart to them the power of undergoing the morphological and chemical differentiation to form the several tissues, and to mould the entire organism so that it may acquire its specific and individual characters.

But with the diffusion of the germ plasma throughout either the whole of the blastoderm, or a part thereof, it is of necessity so intimately associated with the formative cells of the tissues generally, that it is difficult, if not impossible, to comprehend how it can be unaffected by them. Before, therefore, it again becomes stored up or isolated in an individual, in the form of ova or sperm cells, it has in its stage of diffusion been brought under precisely the same influences as those which in the embryo affect the formative cells of the whole body.

If the germ plasma, from the first stage of development of each organism, were completely isolated from the cells from which all the other cells of the body were produced, it would be possible to conceive its transmission from generation to generation unaffected by its surroundings. But as in each individual a stage of diffusion precedes that of differentiation into the special reproductive apparatus, it follows that the conditions which would secure the germ plasma and the soma cells from mutual interaction are not complied with.

THE COAGULATION OF EGG AND SERUM ALBUMEN,
VITELLIN, AND SERUM GLOBULIN, BY HEAT. By
JOHN BERRY HAYCRAFT, M.D., D.Sc., and C. W. DUGGAN, M.B.¹

(From the Physiological Laboratory of the University of Edinburgh.)

A LARGE number of proteid substances, when in solution, are coagulable by heat. As the temperature of such a fluid is raised, faint opalescence at first appears, and then, at a higher temperature, masses (flocculi) of albumen separate out, in most cases, suddenly, from the fluid. It is generally held that each coagulable albumen is so affected at a definite temperature peculiar to itself; thus, egg albumen is said to become opalescent at 60° C., and to separate out in flocculi at 63° C. Unfortunately, hardly two observers agree as to the exact temperature at which opalescence and coagulation occur; thus, keeping to the example, egg albumen, Wurtz puts the coagulation point at 73° C., and Henrijean at 60° to 61° C.

It is hardly possible to explain such differences, either on the assumption that any of the above authors had used imperfect apparatus, or, that they had been guilty of inaccurate observation. It is more probable that the conditions, under which the experiments were performed, were not always the same. What are the conditions which are capable of modifying the coagulation point of albumen? It seemed to us a not unimportant point to investigate systematically these conditions; as such investigation is calculated to throw light on the nature of coagulation itself, and may enable one to arrive at the exact specific coagulation points of the more important proteids, heated as they should always be under exactly similar conditions. The conditions modifying coagulation, which we have studied, are,—the rapidity at which the coagulation is allowed to take place, the degree of concentration of the proteid substance itself, the presence of acids and alkalies, and the presence of soluble salts.

The Rapidity at which Coagulation is allowed to take place.

This is an acknowledged factor varying the indicated temperature of coagulation, and at least one author has alluded to it in the case of the particular albumen studied by himself. If a solution of a coagulable proteid be heated quickly, the proteid will be found to coagulate at a higher temperature than if the heat be applied more slowly. Thus we found that egg albumen, diluted with one volume of water, coagulated at 64° C., when slowly heated, the temperature taking forty minutes to reach this point. Another portion of the same solution coagulated at 66° C., when heated rapidly, the experi-

¹ Communicated to the Royal Society of Edinburgh, July 15, 1889.

ment taking in this case only one minute. It is not difficult to explain this fact. If a drop of an albuminous fluid is mounted for microscopical examination, and, if it be heated on the stage of the microscope, the process of coagulation can be readily followed out. When opalescent, the fluid will be found to contain numbers of tiny granules. These granules increase in size, and apparently become adherent, and run together to form granular masses or flocculi. This naturally requires time, and if the fluid be heated rapidly the temperature may materially increase above the point at which, were the fluid kept for a sufficient time, coagulation would occur. Although our experiments convince us of the general truth of this fact, it occasionally happens that an albumen slowly heated coagulates at a very high temperature, and perhaps never forms distinct flocculi, the coagulation being in the form of a thin jelly. Another portion of the same solution quickly heated coagulates in flocculi at a lower temperature. We have found this occur with some specimens of serum albumen. We are inclined to explain this occurrence on the supposition that the slow and continuous heating in these cases causes some chemico-physical change in the albumen itself, whereby its coagulation is affected.

The Influence on the Coagulation Point of the Degree of Concentration of the Albumen itself.

We find, as the result of our experiments, that in all the albuminous solutions we have investigated, the coagulation point is considerably raised by diluting the solution. A very dilute solution may not coagulate even on boiling, and egg-white, diluted, but nevertheless forming a comparatively strong solution, cannot be coagulated, as Sir William Roberts long ago pointed out.

In our experiments we invariably proceeded in the same way as regards the rapidity with which the solutions were heated, so as to eliminate any fallacy which might arise on this score. The usual method for determining coagulation points was adopted. The solution was placed in a test-tube containing a thermometer which could be used as a stirrer. The test-tube was immersed in a water-bath consisting of two beakers, one within the other, and each one filled with cold tap water. The water-bath was heated by a Bunsen, the flame of which was kept always at the same height, and so arranged that it took some forty minutes for the fluid in the test-tube to reach the temperature of 80° C. All our experiments were performed in this way, so that uniformity of results was obtained. We are inclined to think, however, that the heating process was unnecessarily slow, not only on account of loss of time, but what is more important, because it permitted changes to take place in the albuminous solution, especially when acids or alkalis were present in the fluid.

The Effect of Dilution on the Coagulation Point of Egg Albumen.

Egg albumen was prepared by cutting up the glairy white of an egg and squeezing it through a linen cloth. When this was diluted

with water, the dilute solutions were carefully filtered. The egg albumen was always alkaline in reaction, but we decided not to neutralise it.

In the first experiments the opalescence of the heated solution alone was observed.

- (1) Undiluted egg-white became opalescent at 58° C.
- (2) Egg-white, diluted with one volume of water, became opalescent at 58°·75 C.
- (3) Egg-white, diluted with two volumes of water, became opalescent at 59°·75 C.
- (4) Egg-white, diluted with three volumes of water, became opalescent at 60°·5 C.
- (5) Egg-white, diluted with four volumes of water, became opalescent at 61°·75 C.

In the second experiment the appearance of flocculi was noted as well as the opalescence.

Opalescence appeared in the undiluted egg-white at 59° C., but did not appear so soon in the diluted portions, occurring about 1° C. higher for each dilution.

- (1) The undiluted albumen coagulated with the formation of flocculi at 64° C.
- (2) With one volume of water flocculi formed at 65°·5 C.
- (3) With two volumes of water flocculi formed at 69° C.
- (4) With three volumes of water a few flocculi formed at 80° C., the albumen never completely separating out.
- (5) Greater dilutions showed opalescence, but flocculi did not appear.

The Effect of Dilution on the Coagulation Point of Serum Albumen.

Serum albumen is said by Hoppe-Seyler (iii. p. 232) to become opalescent at 60° C., and to coagulate at 72° C. to 73° C., and Schäfer places it at 70° C. (4, p. 181).

Serum albumen was prepared in the following way:—The serum from bullock's blood was saturated by the hand with magnesium sulphate, the precipitated globulin filtered off; by this means one obtains a solution of serum albumen in a saturated solution of magnesium sulphate. It would have been useless to dilute this solution with water, for, in that case, both the albumen and the magnesium sulphate would suffer dilution. Dilution was effected by the addition of a saturated solution of magnesium sulphate.

(a) Undiluted serum albumen, saturated with magnesium sulphate, becomes opalescent at 77° C., and coagulates at 79° C.

(b) The same solution, diluted with one volume of a saturated watery solution of magnesium sulphate, becomes opalescent at 79° C., and coagulates at 82° C.

(c) When diluted with two volumes, opalescence occurs at 79° C., and coagulation at 83° C.

(d) When diluted with three volumes, opalescence begins at 81° C., and coagulation at 84° C.

(e) When diluted with four volumes, opalescence begins at 81°·5 C., and coagulation at 84°·75 C.

(f) When diluted with five volumes, opalescence begins at 82° C., and coagulation at 85°·25 C.

The numbers quoted do not give us the correct coagulation points for diluted solutions of serum albumen; they are the coagulation points of diluted solutions plus magnesium sulphate, which raises the coagulation point considerably, as we shall subsequently see. The experiment only serves to show how coagulation varies with dilution of the albumen. In this experiment fine flocculi appeared even in the more dilute solutions, and their presence rendered the determination of the coagulation point quite easy, even in the most dilute solutions.

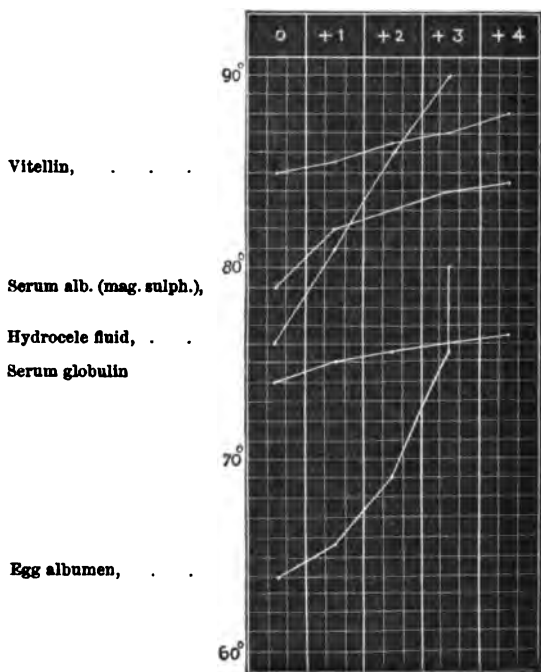


FIG. 1.—Showing the Temperature at which certain Albumens coagulate when diluted with One, Two, Three, and Four Volumes of Fluid.

In order to determine the action of magnesium sulphate, serum albumen was prepared in another way.

Blood serum was diluted with two volumes of water, and a stream of carbon dioxide passed through it. The precipitate of globulin was filtered off. By this method the albumen was obtained mixed with a small quantity of globulin; its presence, however, did not prevent the recognition of the point of opalescence and the coagulation point of the albumen.

(a) The serum albumen became opalescent at 70° C., and coagulated in flocculi at 74°-25 C. The coagulation point being raised two or three degrees above the figure given by Hoppe-Seyler on account of its dilution.

(b) This solution of serum albumen, diluted with one volume of water, became opalescent at 74°, the opalescence becoming very dense at 78° C. No flocculi appeared.

On comparing these figures with those given for serum albumens in a saturated solution of magnesium sulphate, it will be seen that the former are uniformly lower, the presence of magnesium sulphate tending to elevate the coagulation point. The effect of dilution is more marked in the case of serum albumen by itself than in that of serum albumen in the saturated magnesium sulphate solution. In the first place, the coagulation becomes very imperfect in the dilute solutions; in the second place, the temperature in the dilute solution is very much raised.

The Effect of Dilution on the Coagulation Point of Vitellin.

The yolks of several eggs were dissolved in 6 per cent. solution of sodium chloride and filtered. The filtrate was poured into a large volume of distilled water, the precipitate of vitellin redissolved in saline solution, reprecipitated in distilled water, and dissolved in 5 per cent. solution of sodium chloride. In this case the vitellin, prepared from six eggs, was dissolved in 300 c.c. of the solution. In order to study the effect of dilution, a 5 per cent. solution of sodium chloride was added in all cases.

(a) The vitellin solution became opalescent when heated to 80° C., and coagulated at 85° C.

(b) When diluted with one volume of 5 per cent. solution of sodium chloride, the vitellin became opalescent at 81° C., and coagulated at 85°·5 C.

(c) When diluted with two volumes, it became opalescent at 82° C., and coagulated at 86°·5 C.

(d) When diluted with three volumes, it became opalescent at 82° C., and coagulated at 87° C.

(e) When diluted with four volumes, it became opalescent at 83° C., and coagulated at 88° C.

The experiment was repeated, giving a result almost precisely the same. It will be noticed that in this proteid the coagulation point does not vary to a very considerable extent with dilution.

The Effect of Dilution on the Coagulation Point of Serum Globulin.

The coagulation point of serum globulin is given by Halliburton as 75° C. (Reference 6, p. 163).

In the first experiment the globulin was precipitated from bullock's blood by magnesium sulphate. The precipitate was, after washing, dissolved in a 5 per cent. solution of magnesium sulphate. It was diluted with a 5 per cent. watery solution of magnesium sulphate. Unfortunately the opalescence was not noted down. The flocculi were well marked.

(a) The solution of serum globulin in a 5 per cent. solution of magnesium sulphate coagulated at 74° C.

(b) The solution, when diluted with an equal volume of 5 per cent. watery solution of magnesium sulphate, coagulated at 75° C.

(c) When diluted with two volumes, coagulated at 75°·5 C.

(d) When diluted with three volumes, it coagulated at 75°·5 C.

(e) When diluted with four volumes, it coagulated at 76°·25 C.

(f) When diluted with five volumes, it coagulated at 77° C.

(g) When diluted with six volumes, it coagulated at 77° C.

In another experiment serum globulin was prepared by passing a stream of carbon dioxide through dilute blood serum. The precipitated globulin was dissolved in a 5 per cent. solution of sodium chloride. The solution of globulin not being of the same strength (a little weaker), and the salt used for its solution being a different one, the coagulation points do not correspond with those obtained in the previous experiment.

(a) Serum albumen, dissolved in 5 per cent. solution of sodium chloride, became opalescent at 74° C., and coagulated at 79° C.

(b) Serum albumen, dissolved in 5 per cent. solution of sodium chloride and diluted with one volume of a 5 per cent. watery solution of sodium chloride, became opalescent at 77°·5 C., and coagulated at 81°·5 C.

(c) Diluted with two volumes, opalescence commenced at 78°·5 C., and it coagulated at 82°·5 C.

(d) Diluted with three volumes, opalescence commenced at 79° C., and coagulated at 84° C. The albumen at this stage had begun to putrefy, and on repeating the experiments it was found that the coagulation point was raised about two degrees for (a), (b), (c), and that (d) did not coagulate even on boiling.

The Effect of Dilution on the Coagulated Point of Hydrocele Fluid.

Hydrocele fluid contains the same proteids as are found in blood plasma, namely, fibrinogen, serum globulin, and serum albumen. In a case of chronic hydrocele there may be almost an entire absence of proteid matter. The proteid substance when present varies in amount, and the coagulation point varies with it. On diluting hydrocele fluid the coagulation point is raised.

(a) Hydrocele fluid became opalescent at 65° C.; at 72° C. it assumed the consistence of a thin jelly which thickened, and at 76° C. flocculi separated out.

(b) Diluted with one volume of water, it became opalescent at 67° C., and coagulated at 81° C.

(c) Diluted with two volumes of water, it became opalescent at 69° C., and coagulated at 86° C.

(d) Diluted with three volumes of water, it became opalescent at 73° C., and a few flocculi separated out at 90° C.

Another specimen of hydrocele fluid, apparently containing less proteid matter, became opalescent at 70° C., and coagulated with the formation of flocculi at 80°·5 C.

A third specimen became opalescent at 70° C., flocculi forming at 78° C.

General Conclusions regarding Dilution.

In the case of albumens and globulin existing in a natural condition within an animal fluid, such as white of egg, serum, or hydro-

cele fluid, the point of opalescence is gradually and almost uniformly raised by successive dilutions. The coagulation point, on the other hand, rises rapidly, and the more dilute fluids often refuse to form flocculi, or even to coagulate at all.

When a globulin is dissolved in an artificially prepared saline solution, both the point of opalescence and coagulating point are uniformly raised on diluting the solution. The same appears to apply to serum albumen saturated with magnesium sulphate.

The Action of Salts on the Coagulation Point of Albumen.

It is known that the addition of many neutral salts to an albuminous solution has an important action on the temperature at which it coagulates. Some salts are stated to lower and others to raise the coagulation point. It is impossible to explain at present their action, and we have accordingly commenced a somewhat systematic examination of the question. Our results are far from complete, and will subsequently, we hope, be more fully extended.

We have at present studied the action of two important salts, namely, magnesium sulphate and common salt, on the coagulation points of egg and serum albumen, vitellin, and globulin, and the action of these salts has been studied in all degrees of strength up to complete saturation.

Although we feel that it would be quite out of place to attempt general conclusions, yet we believe one or two inferences may be drawn from the facts that we have gleaned.

Some of the facts we have already obtained are sufficiently striking to justify us in thinking that a more extended investigation, made on similar lines, may throw some light on the mutual relationship existing between the albuminous and saline molecules when in solution together. We are aware of the extreme difficulty of the subject, since so little is known as yet regarding simpler problems, such as the mutual relationships that exist between simple mixtures of inorganic salts.

The Action of various Salts on the Coagulation Point of Egg Albumen.

Varenne (Reference 8) finds that many salts by their addition elevate the temperature of coagulation, such are, common salt and sulphate of magnesium; others, such as sulphate of copper and chloride of barium, lower it; while a third series, such as sulphate of sodium and chlorate of potassium, have no effect.

Béchamp (Reference 5, p. 29) finds, on the other hand, that sulphate of magnesium, alum, and the salts of sodium and potassium lower the coagulation point. He came to this conclusion after working with very dilute solutions of albumen; these did not coagulate at all, until after the addition of the salts mentioned. He added very small quantities of the salts to the albuminous solution, viz., less than one per cent. Had he worked with coagulable solutions of albumen, and had he added larger quantities of salt, his result would have been

different. While, as we shall afterwards show, these salts as a rule raise the point of coagulation, it is not at all improbable that dilute uncoagulable solutions of egg albumen may be enabled to coagulate, when they otherwise would not; in fact, our results point to this conclusion. If so, it is only one of the many facts which indicate how little is at present known as to properties of the albuminous molecules and the factors which determine their solubilities.

TABLE I. *showing the Action of various Salts on the Coagulation Point of Egg Albumen.*

Salt added.	Proportion.	Opalescence.	Coagulation.
	Per cent.	° C.	° C.
<i>Original Solution of Albumen,</i>	...	61	65
Lithium chloride,	10	65	70
Sodium chloride,	10	64	66·5
Potassium fluoride,	10	66	71
Potassium chloride,	10	63	68
Potassium bromide,	10	67	77·75
Potassium iodide,	10	67	75
Ammonium chloride,	10	64·5	70
Ammonium nitrate,	10	71	78·5
Ammonium sulphate,	10	67	74
Magnesium chloride,	10	69	75·5
Magnesium nitrate,	10	68	70·5
Magnesium sulphate,	10	65	70
Potassium nitrate,	10	68	76·25
Potassium sulphate,	10	65	68·5

In the preceding table we have placed some of our own results. In all cases the temperature, at which opalescence and coagulation occur, has been raised, though often, as in the case of common salt, to a very slight extent.

The Precipitation of Egg Albumen by Single and by Double Saturation with Neutral Salts.

By complete saturation of an albuminous fluid with a neutral salt the proteid may be precipitated at the temperature of the laboratory. Thus Hammarsten has shown that globulin may be precipitated from serum by the addition of magnesium sulphate. In this case the globulin is not converted into a coagulated proteid, but can again be dissolved after the magnesium sulphate has been diluted.

The Action of Magnesium Sulphate.—The egg albumen was diluted with one volume of water and freed as much as possible from membrane. A portion of this was saturated with magnesium sulphate and filtered. The saturated solution contained about 100 per cent. of magnesium sulphate. In order to obtain solutions of albumen containing a lower percentage of the salt, the saturated solution was diluted with portions of the original albumen.

The original diluted albumen became opalescent at 65° C., and coagulated, forming flocculi, at 65·5 C.

(a) The saturated solution became opalescent at 78° C., and coagulated at 80° C.

(b) Egg albumen, containing 50 per cent. of magnesium sulphate, became opalescent at 67°·25 C., and coagulated at 68°·5 C.

(c) Egg albumen, containing 25 per cent. of magnesium sulphate, became opalescent at 65° C., and coagulated at 67° C.

(d) Egg albumen, containing 12·5 per cent. of magnesium sulphate, became opalescent at 63°·25 C., and coagulated at 65° C.

(e) Egg albumen, containing 6·25 per cent. of magnesium sulphate, became opalescent at 63° C., and coagulated at 65° C.

The action of this salt seems a very curious one, for while in large quantity it raises the coagulation point very considerably, small quantities seem to lower it slightly, and no doubt Béchamp is correct

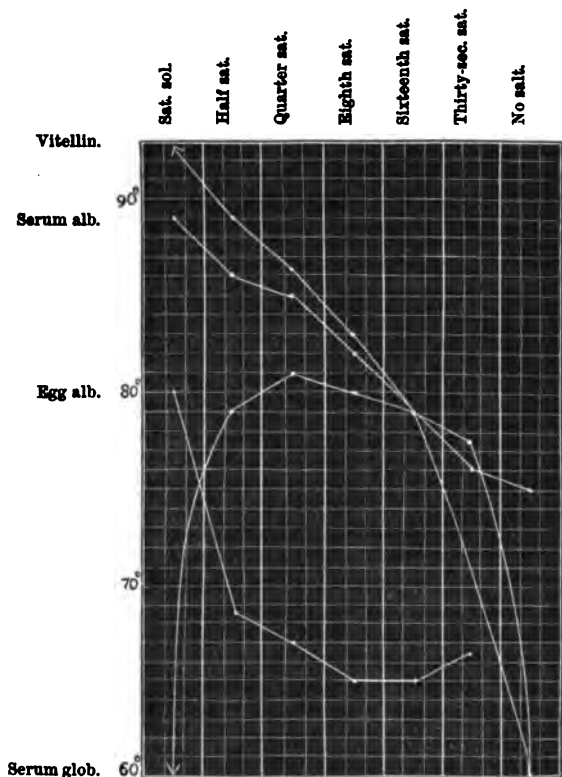


FIG. 2.—Showing the Effect of different Strengths of Magnesium Sulphate on the Coagulation Points of certain Albumens.

when he states that the dilute uncoagulable albumen can readily be coagulated after the addition of the salt. He is hardly, however, justified in speaking of magnesium sulphate as lowering the coagulation point of albumen by its presence.

It is a point of some interest to discover whether a salt, which, by its addition to an albuminous solution, raises the temperature at which coagulation occurs, will produce the same result on an albuminous solution already saturated with another salt. This we have determined to some extent.

Effect of the Addition of various Salts on the Coagulation Point of Egg Albumen already saturated with Magnesium Sulphate.

Egg albumen was diluted with two volumes of water, and saturated with magnesium sulphate. The solution was filtered, and it was found on heating to become opalescent at 79°C. , coagulating at $81^{\circ}\text{--}75^{\circ}\text{C.}$ The salts added, most of which have already been studied in respect to their action on the coagulation point of egg albumen (Table I.), are seen to lower the coagulation point of egg albumen saturated with magnesium sulphate.

TABLE II. *showing the Action of various Salts upon the Coagulation Point of Egg Albumen already saturated with Magnesium Sulphate.*

Salt added.	Proportion.	Opalescence.	Flocculi.
	Per cent.	$^{\circ}\text{C.}$	$^{\circ}\text{C.}$
<i>Albumen saturated with magnesium sulphate,</i>	6	79	81.75
Sodium chloride,	6	72	79
Sodium iodide,	6	...	70
Sodium sulphate,	6	79	81.5
Potassium chloride,	6	72	79
Potassium bromide,	6	70	74
Potassium nitrate,	6	70	73.75
Potassium chlorate,	6	71	74.5
Potassium sulphate,	6	74	77
Ammonium chloride,	6	62	73
Ammonium nitrate,	6	63	65

On comparing this table with that on page 295, it will be noted, first, that those salts which on Table I. do not raise the coagulation point of egg albumen to any great extent, NaCl , KCl , K_2SO_4 , and Na_2SO_4 (Varenne), do not lower the coagulation point (Table II.) to any great extent. On the other hand, salts like KBr , K_2NO_3 , and NH_4NO_3 , which raise the coagulation point in Table I., depress it in Table II. It is possible still more to lower the coagulation point by the addition of larger quantities of the latter salts, until one can precipitate the albumen by double saturation at the temperature of the laboratory. On the other hand, the addition of large quantities of NaCl and Na_2SO_4 exerts very little action.

Effect of Magnesium Sulphate on the Coagulation Point of Serum Albumen.

Although Dr Halliburton has succeeded (Reference 6, p. 192) in precipitating serum albumen by double saturation by means of sulphate

of magnesium in conjunction with such salts as sodium sulphate, sodium nitrate, potassium iodide, &c., magnesium sulphate in itself raises the coagulation point of serum albumen.

(a) Serum albumen, containing 100 per cent. magnesium sulphate, became opalescent at 84° C., and coagulated at 89° C., a slight opalescence appearing at 40° C., due to a trace of serum globulin.

(b) Serum albumen, containing 50 per cent. magnesium sulphate, became opalescent at 77° C., and coagulated at 86° C.

(c) Serum albumen, containing 25 per cent. magnesium sulphate, became opalescent at 76° C., and coagulated at 84°·75 C.

(d) Serum albumen, containing 12½ per cent. magnesium sulphate, became opalescent at 72° C., and coagulated at 82° C.

(e) Serum albumen, containing 6½ per cent. magnesium sulphate, became opalescent at 74° C., and coagulated at 78°·25 C.

(f) Serum albumen, containing 3½ per cent. magnesium sulphate, became opalescent at 72° C., and coagulated at 76° C.

(g) Serum albumen, somewhat diluted in this experiment, became opalescent at 68° C., and coagulated at 75° C., without the formation of well-marked flocculi.

Sodium Chloride.—Although Hoppe-Seyler states that this salt lowers the coagulation point of serum albumen, we find that this is only the case when present in large quantity. Small quantities appear, if anything, to raise it.

A saturated solution of the same serum albumen as that used for the last experiment coagulated at 72° C., when saturated with common salt. A solution, containing 20 per cent., became opalescent at 74° C., and coagulated at 80°·5 C.

The Action of Sodium Chloride on a Solution of Serum Albumen already saturated with Magnesium Sulphate.

In this case the coagulation was lowered as sodium chloride was added in greater and greater quantity.

(a) Serum albumen, saturated with magnesium sulphate, became opalescent at 77° C., and coagulated at 79° C.

(b) The same solution, plus 10 per cent. sodium chloride, became opalescent at 72°·5 C., and coagulated at 75° C.

(c) The same solution, plus 20 per cent. sodium chloride, became opalescent at 70° C., and coagulated at 73° C.

A larger quantity of common salt was not added, since 20 per cent. did not dissolve readily.

The Action of Magnesium Sulphate on the Coagulation Point of Vitellin.

Some vitellin was dissolved in a dilute solution of magnesium sulphate. Some of this was saturated with the salt, the precipitate filtered off, and the filtrate tested.

(a) Vitellin, dissolved in a saturated solution of magnesium sulphate (100 per cent.), became opalescent at 88° C. Coagulation did not occur even on boiling, a few flocculi alone appearing.

(b) Vitellin, dissolved in a 50 per cent. solution of magnesium sulphate, became opalescent at 87° C., and coagulated at 89° C. with flocculi.

(c) Vitellin, dissolved in a 25 per cent. solution of magnesium sulphate, became opalescent at 81° C., and coagulated at 86°·5 C.

(d) Vitellin, dissolved in a solution containing 12·5 per cent. magnesium sulphate, became opalescent at 74° C., and coagulated at 82°·5 C.

(e) Vitellin, dissolved in 6·25 per cent. solution of magnesium sulphate, became opalescent at 74° C., and coagulated at 79° C.

(f) Vitellin did not completely dissolve in 3½ per cent. solution of magnesium sulphate. It was not heated.

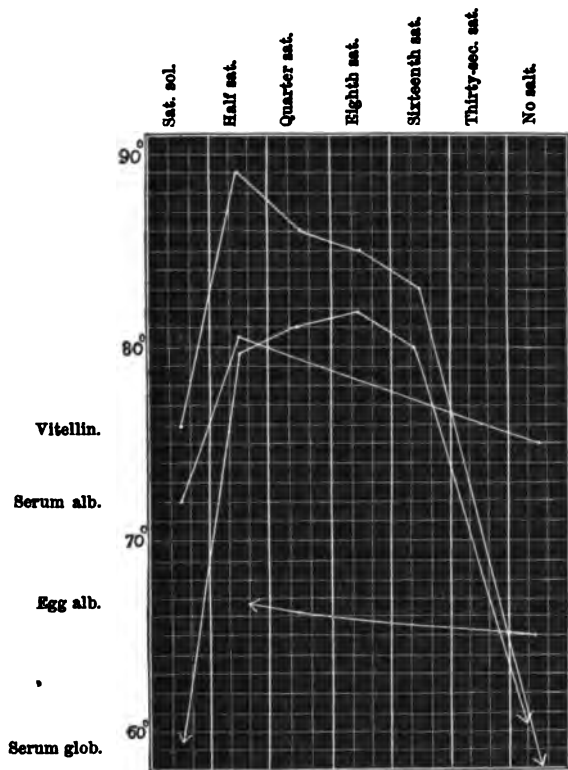


FIG. 3.—Showing the Effect of different Strengths of Sodium Chloride on the Coagulation Points of certain Albumens.

When further diluted until only about 1 per cent. magnesium sulphate was present, a distinct precipitate separated out in the cold.

This experiment was repeated with a more dilute solution of vitellin. The coagulation points at corresponding strengths of the magnesium sulphate were all higher. The result was otherwise the same, the saturated solution requiring the greatest temperature for its coagulation.

The Action of Sodium Chloride on the Coagulation Point of Vitellin.

Some vitellin was dissolved in 5 per cent. solution of common salt. It was saturated with the salt, and a precipitate of globulin filtered off.

(a) Vitellin, dissolved in saturated solution of common salt, became opalescent at 70° C., and coagulated at 76° C.

(b) Vitellin, dissolved in 20 per cent. solution of common salt, became opalescent at 83° C., and coagulated at 89° C.

(c) Vitellin, dissolved in 10 per cent. solution of common salt, became opalescent at 80° C., and coagulated at 86° C.

(d) Vitellin, dissolved in 5 per cent. solution of common salt, became opalescent at 79° C., and coagulated at 85° C.

(e) Vitellin, dissolved in 2.5 per cent. solution of common salt, became opalescent at 78° C., and coagulated at 83° C.

This experiment was repeated, and showed that common salt raises the coagulation point of vitellin, but that it is lowered just before the point of saturation, and that it continues to be lowered until saturation occurs.

Action on the Coagulation Point of Vitellin of both Common Salt and Magnesium Sulphate dissolved together in the Solution.

If, to vitellin in a saturated solution of common salt, some magnesium sulphate be added, the latter dissolves with difficulty, precipitating the vitellin in flocculi; on heating, other flocculi appear.

If, to vitellin in a saturated solution of magnesium sulphate, common salt be added, the coagulation point is lowered. Thus, on adding 15 per cent. of common salt, coagulation occurs at 88° C., and with a little over 20 per cent. it is lowered to 70° C.

Serum Globulin.—Serum globulin is precipitated by magnesium sulphate in excess, as Hammarsten has shown. The same observer obtained a precipitation by saturating with common salt.

The Action of Magnesium Sulphate on the Coagulation Point of Serum Globulin.

Serum globulin was precipitated from the serum of ox's blood by passing a stream of CO₂ through it. The precipitate after careful washing was dissolved in magnesium sulphate solution.

(a) Serum globulin is precipitated in the cold by saturating the solution with magnesium sulphate.

(b) Serum globulin, dissolved in a solution containing 50 per cent. magnesium sulphate, became opalescent at 74.5° C., and coagulated at 79° C.

(c) Serum globulin, dissolved in a solution containing 25 per cent. magnesium sulphate, became opalescent at 78.5° C., and coagulated at 80.75° C.

(d) Serum globulin, dissolved in a solution containing 12.5 per cent. of magnesium sulphate, became opalescent at 77.5° C., and coagulated at 80° C.

(e) Serum globulin, dissolved in a solution containing 6.25 per cent. of magnesium sulphate, became opalescent at 76° C., and coagulated at 78.75° C.

(f) Serum globulin, dissolved in a solution containing 31.25 per cent. magnesium sulphate, became opalescent at 71°5 C., and coagulated at 77° C.

Effect of Sodium Chloride on the Coagulation Point of Serum Globulin.

(a) Serum globulin, saturated with sodium chloride, is precipitated in the cold.

(b) Serum globulin, containing 20 per cent. sodium chloride, became opalescent at 77° C., and coagulated at 79°5 C.

(c) Serum globulin, containing 10 per cent. sodium chloride, became opalescent at 79° C., and coagulated at 81° C.

(d) Serum globulin, containing 5 per cent. sodium chloride, became opalescent at 79° C., and coagulated at 81°75 C.

(e) Serum globulin, containing 2.5 per cent. sodium chloride, became opalescent at 78° C., and coagulated at 80° C.

(f) Serum globulin in much smaller quantity does not dissolve to form a clear solution.

Tentative Conclusions regarding the Action of Salts.

(1) A salt may raise the temperature of coagulation if present in a certain percentage; at another percentage it may lower it. Thus common salt raises the coagulation points of both vitellin and serum globulin when present in moderately small quantity. Large quantities lower the coagulation point.

(2) If a proteid be present in a saturated solution of a salt—such as magnesium sulphate—and, if another salt be then added, which by itself would raise the coagulation point, the coagulation point may in this case be lowered. It appears, too, that salts which are most active in raising the coagulation point are most active in lowering it, when added to a solution already saturated by another salt.

Statement as to whether it is possible to speak of the Specific Coagulation Point of an Albumen.

From what has been already said, it is obvious that it is a difficult and perhaps a valueless task to attempt to determine what may be termed the "specific coagulation point" of an albumen. The coagulation point varies with the rapidity of heating, with the concentration of the fluid, with its reaction, and with the saline substances present. All that one can say is that, under such and such conditions, an albumen coagulates at such a temperature. It is probably hardly possible to obtain even two albumens under such similar conditions that their coagulation points may with advantage be compared. The nearest approach to this would perhaps be to dissolve a certain weight, say both of vitellin and another globulin such as serum globulin, in the same volume of salt solution. The coagulation points may, in this case, with advantage be compared. But what would be the value of the coagulation points so obtained for purposes of comparison with serum or egg albumen dissolved in water? The coagulation

points quoted by previous writers cannot be taken in any sense as absolute values for the albumen named, modifying conditions having, as a rule, been totally disregarded. The same may be said of our own results, for the percentage strengths of the albuminous solutions used by us were in no case determined with any care. Although the forms of the curves represented in the charts are not affected by this, their altitudes in the scale of temperatures may be so to some considerable extent.

On so-called Fractional Coagulation.

So far we have been dealing with albumen in its natural condition, or mixed and possibly combined with neutral salts which we had added.

The solutions were alkaline, and, as we found, when dealing with the natural albuminous solution, difficult to coagulate, especially if in a dilute condition. Let us now consider the coagulation point of an albuminous solution to which an acid has been added. On adding an acid to an albumen solution, the coagulation is rendered, as every one knows, more easy, and it occurs at a lower temperature. The very dilute solutions, uncoagulable in the alkaline solution, are at once coagulated after the addition of a few drops of weak acid. No one has brought this out more clearly than Dr Halliburton in a most suggestive paper (Reference 6), which will presently be quoted in relationship to fractional coagulation. He showed that the coagulation point of serum albumen varies with the amount of acid present, the greater the quantity added, the lower the coagulation point, until finally coagulation could be produced at the temperature of the laboratory. If then the coagulating point depended on the two factors, heat and the amount of acidity, it seemed to him a natural deduction, that, on keeping one of these, the acidity, a constant quantity, it might be possible to separate by fractional coagulation two or more albumens mixed together, and having different coagulation points. He investigated serum albumen, and found that if it be neutralised by the addition of some drops of a 2 per cent. solution of acetic acid, and if, further, it be rendered slightly acid by the addition of one drop of the dilute acetic acid to seventy-five drops of the albuminous solution, then it coagulates at 70° to 71° C., and if this coagulum be filtered off, and the solution again brought to the same degree of acidity, a coagulum occurs the second time at 77° to 78° C. If this coagulum be filtered off and the filtrate acidified as before, a third coagulum may be produced at 82° C. Dr Halliburton considers that the serum albumen, originally regarded as one proteid, in reality consists of three.

MM. Corin and Berard have followed this process of fractional coagulation, applying it to egg-white. This substance, commonly held to consist of albumen and globulin, they believe to consist of three albumens and two globulins.

They neutralise some egg-white, slightly acidify it, and raise its temperature, until opalescence appears; then they keep the tempera-

ture constant for a considerable time—an hour or even more. They filter off the coagula, re-acidify to the same degree, raise the temperature until opalescence occurs, and then after more prolonged heating flocculi again appear.

In this way they have succeeded, as stated, in fractionating five proteids.

Without doubting that it may be possible to fractionate some proteids, nevertheless the results of our own work, and many of the facts frankly stated by Dr Halliburton, seemed to throw some doubt upon the correctness of his deductions in the case of serum albumen, and this applied with equal force to the experiments conducted by MM. Corin and Berard on egg albumen.

Our previous experiments have shown that, in alkaline solution, the more dilute a solution is, the higher is its coagulation point, and we have found that we could never completely precipitate any albumen at the temperature at which flocculi first appeared. The reason of this is very simple; as soon as a solution begins to coagulate, the remnant, still soluble, is practically a more dilute solution of the same proteid, and must be heated two or three degrees more before it will begin to precipitate. In this case, also, the coagulating proteid will leave another soluble remnant, coagulable at a still higher temperature, and so on. In fact, we may venture to make this general statement—*In order to coagulate completely any proteid it must be heated to that temperature at which its most dilute solutions are coagulable.* We have not made so systematic an investigation upon the effect, on its coagulating point, of diluting acid solutions of albumen, but we have assured ourselves that the more dilute solutions coagulate at a higher temperature. One out of several experiments may be quoted the following:—

Some egg albumen was diluted with two volumes of water and carefully neutralised. It was then brought to the same degree of acidity as is recommended for fractional coagulation, 1 cubic centimetre of a 2 per cent. solution of acetic acid being added to 75 cubic centimetres of the albumen. This solution was found to coagulate at 53° C.

When diluted with one volume of water, acidulated to the same degree, it coagulated at 54° C.

With three volumes of water, it coagulated at 58° C.

With seven volumes of water, it coagulated at 62° C.

With fifteen volumes of water, it coagulated at 68° C.

It is seen, therefore, that dilution has the effect of raising the coagulation point a great many degrees, the more dilute albumen requiring a much higher temperature for its separation. This may be shown in the most striking manner by heating some of the acidulated water to between 60° and 70° C.; and dropping in some acidulated egg albumen it at first dissolves. Now divide the solution into two portions, A and B, and heat A to 75° C., and keep B at the original temperature. A will coagulate, showing that although in too dilute a solution to coagulate below 70° C., it could nevertheless coagulate, provided its temperature be raised. B will remain clear, but, if more

albumen be dropped into it, a point will be reached, at which it will cease to dissolve, and then it will separate out in flocculi.

Here then, without going any further, one has come across an observation which, if it does not explain all the facts described under the head of fractional coagulation, must at any rate account for some of them.

Both Dr Halliburton and MM. Corin and Berard found that after coagulation the filtrate, which they separated from the clot, was less acid than it was before coagulation had occurred, the latter observers finding that, as a rule, it was actually alkaline. Here, again, is a factor which we cannot afford to lose sight of. If the coagulation point is lowered by acidity, as all persons are agreed, one would expect that, while coagulation is proceeding, and while *pari passu* the acidity is decreasing, that the decrease of acidity would at last bring the coagulation—at that temperature—to a standstill. In this case one would expect, that on re-acidifying to the same degree, another crop of coagula might fall at the same temperature as did the first crop.

Dr Halliburton does not mention any such coagulation, although undoubtedly it occurs, and we have found it on repeating his observations, but MM. Corin and Berard evidently find that one is produced, and in consequence they heat the albumen for an hour or more before filtering off the coagulum. After this time, they found that the albumen never gave a second coagulation at the same temperature. We cannot but conclude from this that their experiments clearly indicate that the albuminous solutions with which they worked must have been very materially changed by the temperature, nor is it at all improbable that very material changes may occur in a solution of egg albumen kept in an acid solution at a high temperature for over an hour; in one of their quoted experiments fractionation lasted over six hours.

We may, we think, make this statement, and one fully borne out by our own experiments, that during coagulation in an acid medium the coagulation point is being continually raised, both in virtue of the albumen becoming more dilute and in virtue of its becoming less acid; these factors bring the coagulation to a standstill, but, after filtering off the coagulum, if the fluid be brought back to its original degree of acidity, and heated to the same temperature, coagula will again form, unless the albumen has undergone some physico-chemical change.

It follows, too, that it is impossible to separate two albumens from one another by heat coagulation, unless, during the process of coagulation, the degree of acidity is kept uniform by the addition of small quantities of fresh acid, and unless the coagulation point of the *most dilute solution* of one of the albumens present be below the coagulation point of the other albumen. We became more convinced of this, when repeating in detail the experiments on fractional coagulation. After keeping an albuminous solution, either egg or serum albumen, at the temperature at which flocculi appear, for five or six minutes, and then filtering off the flocculi, we found that fresh flocculi appeared,

when the filtrate had been re-acidified, and again raised to the same temperature. Two or three crops might be thus removed in the case of egg-white. Keeping up the same degree of acidity, and raising the temperature, we were able to get other crops of albumen. We were struck, however, by the fact that, while dealing with the more dilute albumen, the coagulation took place with difficulty, and it was longer delayed. This was particularly the case with egg albumen. If the fluid filtrate from the flocculi be divided into two parts, and one portion raised gradually in temperature, opalescence followed by the formation of flocculi will appear. If the other portion be raised in temperature and kept for, say, three minutes at a temperature one or two degrees below the temperature at which opalescence appeared in the first portion, it will become opalescent and perhaps form flocculi. We found, in fact, that it was impossible to get the subsequent coagulation at definite points, as indicated by the previous observers, for the coagulation point depended upon the way in which the operations had been carried out. This was especially the case, when dealing with egg albumen, and we have little doubt that MM. Corin and Berard, working with careful method, invariably raised their temperatures to points which perhaps their first experiments had suggested. They, no doubt, produced coagula, but, had they tried the experiment, they would have obtained them equally well at a lower temperature, provided they had raised the temperature more slowly. It is not difficult to fractionate egg albumen ten or twelve times.

Another point that struck us was the smaller and smaller amount of coagulation produced, as the temperature of the solution was raised and successive crops produced. This was noticed by Dr Halliburton in the case of egg albumen. It is certainly the case with egg albumen. This, of course, in itself renders it highly probable that we are dealing in both cases only with one albumen, the more dilute solutions of which are alone coagulated at the higher temperatures. Even supposing that the γ serum albumen of Dr Halliburton, of which he "in some case only found a trace," and which coagulates at 82° C., is different from α and β serum albumen, found in greater quantity, and coagulating at lower temperatures, yet fractional coagulation could not give us the means of proving this. One cannot compare the coagulating points of a dilute with a strong solution of two albumens, and presuming that γ serum albumen is a dilute solution differing from α and β , yet its coagulation point would be lower than 82° C. in a solution of corresponding strength.

It is, of course, possible that serum albumen may consist of more than one albumen, although it is probable, from what we have brought forward, that all the albuminous matter present coagulates at the same degree of concentration—at or about the same temperature. Other methods may enable the physiologist to separate these, if they exist, from one another, and no methods have in the past yielded such valuable results as those in which separation has been obtained by the addition of neutral salts. Dr Halliburton has by this means

306 COAGULATION OF EGG AND SERUM ALBUMEN BY HEAT.

tried to separate the α , β , and γ serum albumens from one another, and frankly states that he failed to do so (Reference 6, p. 173).

This paper contains some of the results of a research, towards the expenses of which a grant of money was voted by the Scientific Grants Committee of the British Medical Association.

Papers referred to in the Text.

1. WURTZ, *Diction. de Chemie*, article "Albumine."
2. HENRIJEAN, *Contributions à l'étude de l'antisepsie*.
3. HOPPE-SEYLER, *Handbuch der Chemischen analyse*.
4. SCHÄFER, *Journal of Physiology*, vol. iii.
5. J. BÉCHAMP, *Nouvelles Recherches sur les Albumines*.
6. W. D. HALLIBURTON, "On Proteids of Serum," *Journal of Phys.*, vol. v.
7. MM. CORIN and BERARD, *Travaux du Laboratoire de Léon Fredericq*, vol. ii, 1887-8.
8. M. C. VARENNE, *Recherches sur du Coagulation de l'albumine Jahresberichte Anat. u. Phys.*, 1886, p. 249.
9. HAMMARSTEN, *Archiv f. die Gesamte Physiol.*, Bd. xvii., 1878.

A TUMOUR IN THE FRESH-WATER MUSSEL (*Anodonta cygnea*,
Linn.). By JOSEPH W. WILLIAMS, *Middlesex Hospital Medical
School*.

THE subject of the present communication is a pediculated tumour, of about the size of a hazel-nut, found by me on the internal aspect of the left pallial-lobe of a Fresh-water Mussel (*Anodonta cygnea*) taken from a private fish-pond at Hendon, Middlesex. It is an ovoidal-shaped mass in direct continuity with the pallium by a short and somewhat narrow pedicle. The apex or narrower end of the tumour freely depended into the infra-branchial chamber, and on examination of the internal nacreous layer of the shell there was present no impression which could be regarded as abnormal, or as marking the presence of the growth. Looking at it without a microscopical examination, it suggested the appearance of the rare polypoid forms of myoma found in the œsophagus, stomach, and intestine of mammals. Transverse sections stained with hæmatoxylin and picrocarmine, and examined with $\frac{1}{8}$ th inch objective, proved it, however, to consist of gland-cells and muscle-bundles. The gland-cells could not be distinguished in microscopical character from those normally found in the glandular margin of the mantle; they were present, for the greater part, in the broader end of the tumour, viz., on that portion of it which looked towards the internal pallial surface. The muscle-bundles formed the middle and apical portions of the growth, and were not regularly arranged, some running in a longitudinal direction, some transversely, and others in an oblique fashion. In one of the sections examined, a bundle of muscle-cells was seen running in a downward direction through the glandular portion of the growth. This was all the structure which I could discern with the microscopical appliances at my disposal. Classified, the tumour may be considered as an adeno-myoma. It will be noticed that the tumour-pedicle, springing as it did from a point on the inner surface of the pallial-lobe corresponding to the situation of the pallial line on the shell, was distant by several millimetres from the region of the gland-tissue (glandular margin), and yet contained gland-cells in its composition. Whether the presence in it of these gland-cells can be legitimately explained by Cohnheim's "hypothesis of embryonic remains," I will not determine. As far as I am aware—I have

searched the majority of conchological literature—the specimen is unique.

I collected seven hundred mussels from this pond, and in this specimen only could I find a growth of tumour character. In seven I found in the mantle what could be called simple parenchymatous-cysts. Two of these were “pedunculated,” and dependent into the infra-branchial chamber. All were, as was evident from their general characters, produced simply by a fusion of connective-tissue spaces filled with water or hæmolymph. I could demonstrate no special cyst-walls; their walls were formed by the normal tissue of the mantle.

PROCEEDINGS OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

NOVEMBER 1889.

THE Annual General Meeting was held on November 27, at the London Hospital, the President in the chair. Present—Twenty-four members and visitors. The Auditor's report, showing a balance of £10, 14s. 6d. to the Society's credit, was laid on the table.

The following gentlemen were elected Officers for the ensuing year:—*President*, George Murray Humphry, M.D., F.R.S. *Vice-Presidents*, Sir William Turner, M.B., F.R.S.; Daniel John Cunningham, M.D.; George Dancer Thane. *Treasurer*, Charles Stewart. *Secretaries*, W. P. Herringham, M.D. (England); H. St John Brooks, M.D. (Ireland); John Yule Mackay, M.D. (Scotland). *Council*, Wm. Anderson; John T. Charles, M.D.; John Curnow, M.D.; J. N. C. Davies-Colley; John Cleland, M.D., F.R.S.; Rickman J. Godlee; G. B. Howes; David Hepburn, M.D.; John Langton; Charles Barrett Lockwood; Alexander Macalister, M.D., F.R.S.; A. M. Paterson, M.D.; Thomas Pickering Pick; J. Bland Sutton; John Struthers, M.D.; John Symington, M.D.; Frederick Treves; Bertram Windle, M.D.; Arthur Thomson, M.B.; Alfred H. Young, M.B.

J. Dundas Grant, M.D., was elected a member of the Society.

Dr H. ST JOHN BROOKS showed models illustrating the *Topographical Anatomy of the Abdomen*.

Drs SHORE and LEWIS JONES showed *Sections of the Liver* in a series of vertebrates, including the Eel, Newt, Coscilian Tortoise, Chick, and embryo Mammal, and pointed out the significant fact that in every case the liver tubules were arranged in a network. They had been unable to find any instance of a liver with tubules that did not anastomose, and from that they argued that the liver was developed from a solid mass of cells, by the entry of blood-vessels to form intertubular spaces, and that the network was not the result of an anastomosis of tubules originally separate. The special features of

the mammalian liver were that it was a tubular gland, having its network obscured by the great condensation of its tissue, and by the fineness of its meshwork; in fact, that it presented a far more intimate penetration and subdivision by blood-vessels than was to be found in the lower vertebrates.

Mr J. J. CLARKE showed a Heart with *Abnormal Pulmonary Valve*, sent to him by Mr H. A. Kidd. The pulmonary valve was quadruple, each flap presenting all the characteristic parts. These cases were interesting in reference to the development of these valves in the Chick, as described by Morris Tonge in *Phil. Trans.*, 1869. The last of the three rudiments to appear is that on the outer wall of the aorta and pulmonary artery—that is, on the side of the vessel opposite the septum. This rudiment may develop into one, two, or three segments, according to the amount of space left by the other two.

Mr THANE pointed out that one of the flaps on the outer wall of the vessel was considerably smaller than the others. This fact supports the view that the additional flap has its origin in the external rudiment.

Professor WINDLE exhibited specimens of *Ununited Epiphyses*.

1. *Acromial*.—(a) Four of apical epiphyses, obtained from two subjects. The epiphysis in each case existed as a triangular fragment of bone of an average length of 2.0 cm., and breadth of 2.5 cm., forming the point of the acromion; (b) a pair from the same subject of bordering epiphyses which formed a narrow band, 5.0 cm. long and 1.0 to 2.0 cm. broad, fringing the whole of the end of the acromion; (c) a single specimen in which the epiphysis formed the greater part of the spine, being 8.5 cm. in length, the total length of the spine and acromion being 14 cm. In this case the coracoid was also separated, the epiphysis being much larger than that usually observed, the depth of the fragment being 3.0 cm. The fellow scapula had unfortunately been disposed of from the dissecting-room before the condition was noticed. It was thus impossible to say whether the conditions were bilateral. When examined, there existed between the epiphyses and body in each case what appeared to be a plate of cartilage; (d) two scapulæ with large irregular ended acromia, from the same subject, with small detached fragments of bone bound to each by ligament. The condition resembled that met with in chronic rheumatoid arthritis, of which, however, there was no trace in the joints. The nature of these specimens was very doubtful, possibly a partial ossification of ligament being the explanation.

2. *Of Internal Condyle*.—A humerus from which the epiphysis of the internal condyle was separated on one side only. The condyle was stunted in its growth, resembling a rounded button, and was bound by strong fibrous tissue to the lower end of the supra-condyloid ridge, which was considerably thickened.

Mr POLAND maintained that the condition was due to fracture.

Professor A. M. PATERSON described a case of *Fracture of Cervical Vertebrae*.

The cause of the present lesion was judicial suspension. The axis was fractured through both pedicles, causing separation of the arch from the body and odontoid process; and on the left side the transverse process was broken off. In the third vertebra the transverse process was fractured on the right side, and incompletely on the left also.

The following was the condition of the parts after death:—(1) separation of the body of the axis from that of the third vertebra, with adherence of the intervertebral substance to the former, and rupture of the anterior and posterior common ligaments; (2) rupture of the posterior atlanto-axial ligament, with adherence of the arch of the axis to that of the 3rd vertebra; (3) rupture of the soft structures connecting the transverse processes of the 2nd and 3rd vertebrae together, including the vertebral artery; (4) rupture of the spinal membranes and cord, opposite the interval between the 2nd and 3rd vertebrae, and laceration of the roots of the 2nd cervical nerves.

In relation to this specimen, it is worthy of note, that the intervertebral disc between the 2nd and 3rd cervical vertebrae lies at the level of the chin when slightly raised, and that the parts above that—the atlas, body, and odontoid process of the axis—retained their normal relations after death. The odontoid process still remained within the transverse ligament. The immediate cause of death was rupture of the spinal cord, which would occur, *pari passu*, with the fracture of the vertebrae. The force exerted to produce the lesions may be roughly estimated at 1 ton 8 cwt., as the weight was 10½ st., the length of drop 6½ feet.

The following paper by Dr BERTHOLD BEER of Vienna, *on the Development of the Sylvian Fissure in the Human Embryo*, was then read.

The development of the persistent convolutions and fissures of the hemispheres is preceded by the appearance of *primitive convolutions*, as they are called by Koelliker, which have been already described by Tiedemann, F. Schmidt, and A. Ecker. They may be seen already in a fœtus of the third month, and disappear in the fifth month, when the lateral surface of the hemispheres becomes smooth again. These primitive convolutions are not artificial products produced by the action of hardening solutions, as has been supposed by Bischoff, but they are produced by folding of the thin hemisphere, due to compression by the enveloping meningeal membranes. There are folds projecting into the cavity of the hemisphere which correspond to the fissures of the outer surface, as I could state in the cerebrum of a human fœtus of the twelfth week, examined three hours *post-partum* in a perfectly fresh state. The number of the primitive fissures being

three or four on the lateral surface of the hemisphere in the third month, is increased in the fourth month as may be seen by the drawing (fig. 1, *P.S.*), and their situation is also altered by the growth of the brain. In the third month, they show a radiating arrangement converging downwards to the angle where the frontal and temporal ends of the hemisphere are lying close together, while in the fourth month only traces of this radiation could be observed. It may also be

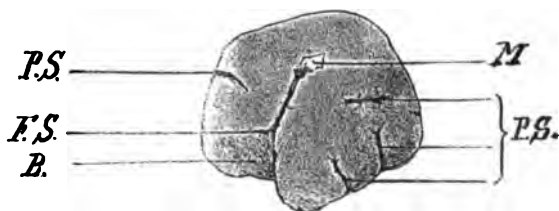


Fig. 1.

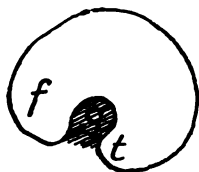


Fig. 2.

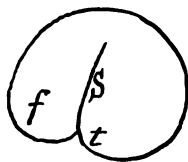


Fig. 3.

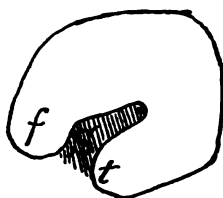


Fig. 4.

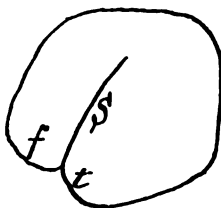


Fig. 5.

FIG. 1.—Lateral Surface of the Left Hemisphere of a Human Foetus (12–14 weeks old). *P.S.*, primitive fissures; *F.S.*, Sylvian fissure; *B.*, basal surface; *M*, part of meningeal membrane filling the Sylvian fissure.

FIGS. 2, 3, 4, 5.—Schematic Diagrams of the Left Hemisphere. *f*, frontal lobe; *t*, temporal lobe.

FIGS. 2, 4.—After *Ecker*. *S*, Sylvian groove with the floor (*Insula Reili*).

FIGS. 3, 5.—Original. After removal of meninges. *S*, Sylvian fissure.

stated, that even in the same brain the development of the primitive fissures shows inequalities, and frequently the left hemisphere shows a higher development of the fissures than the right. Besides the primitive fissures, I had opportunity to see on the hemispheres of the fourth month a system of very small gyri and sulci, resembling the convolutions of the adult brain on a diminished scale. These small gyri are especially well developed in the occipital part of the hemi-

sphere, and are due to inequalities in the histological development of the wall of the hemisphere. They have not been described till now, and should not be confounded with the shagreen-like appearance of the surface of foetal brains produced by the action of hardening agents. The *microgyri*, just described, I could see in an embryo of the fourth month, examined an hour *post-partum*, shining through the transparent meningeal membranes. The primitive fissures disappear, as is well known, in the fifth month, with the exception of the Sylvian fissure on the lateral surface, and of the sulcus hippocampi and sulcus parieto-occipitalis on the median surface. According to Ecker, Mihalkovics, &c., the Sylvian fissure of the adult is formed by the gradual narrowing of a flat, broad depression on the lateral surface of the hemisphere, which is due to arrest of development of the insula Reili in the third month of foetal life. Ecker arrived at this conclusion by observations made on foetal brains hardened by chloride of zinc injections. On foetal brains of the third and fourth month, examined by me in a perfectly fresh state a few hours *post-partum*, I could also see the grooves described by Ecker as long as the brain was covered by the meningeal membranes, *but as soon as the meninges were removed*, it could be seen that the hemisphere on its lateral surface was divided into two lobes (*f, t*, figs. 3, 5), by a *long and deep fissure* (fig. 1, *F.S.*; figs. 3, 5, *S.*), running in a nearly vertical direction to the base, and the groove-like appearance had only been produced by the mycomatous tissue surrounding the cortical blood-vessels covering the angle, where the frontal and temporal ends (figs. 3, 5, *t.*), are touching each other. The relation of the different parts will be easily understood by perusal of the accompanied figures. The insula Reili is not marked out in the foetus of third or fourth month on the lateral surface of the hemisphere, but at the end of the fifth month, by the formation of short fissures lying in the frontal lobe and directing its concavity to the neighbouring Sylvian fissure, the Sylvian groove is formed, which becomes closed later by the intensive growth of the operculum.

A full description of the morphological and histological development of the foetal hemisphere will soon be published.

Professor CUNNINGHAM read the paper upon the *Intraparietal Fissure of the Human Brain*, which is printed *in extenso* in the *Journal of Anatomy and Physiology*, p. 135.

The following paper was read at the August Meeting of the Society; its publication has been unavoidably postponed until now:—*On the Distribution of the Cutaneous Nerves of the Trunk, with special reference to Herpes zoster*, by Professor WARDROP GRIFFITH and Dr OLIVER.

For some years one of the writers (Dr Griffith) had had a difficulty in reconciling the distribution of the cutaneous affection in herpes zoster with the ordinarily accepted views of the distribution of the cutaneous nerves.

The descriptions in all the text-books were based on Hirschfeld's diagrams, and a consideration of these would lead one to expect that if the posterior group of vesicles of a case of herpes zoster occupied an area corresponding say to the 11th or 12th dorsal spines behind, its anterior group would occupy an area below the level of the umbilicus; and, on the other hand, that in a case with the anterior group at the epigastric region, the posterior group would be about the mid-dorsal region.

That this was not the case was shown by a series of charts he had made, which all agreed in demonstrating that the posterior group of vesicles was always much lower with reference to the anterior than would be expected. This was especially noticeable when the disease affected the lower part of the chest.

He had also noticed, as bearing on this point, that the upper limit of the anæsthesia in cases of paraplegia was transverse, or almost so, corresponding in fact with the line of herpes, and not oblique, as would be expected from the accepted anatomy.

A series of dissections had been undertaken by the writers, and the following was a summary of their results:—

1. The distribution of the anterior primary divisions of the intercostal nerves, as given by Hirschfeld, is accurate, and is strictly followed by the cutaneous distribution of herpes.

2. The posterior primary divisions of the intercostal nerves pass very obliquely downwards, and are distributed to the skin several inches—in some cases as many as six—below their origin. Thus in one case it was found that the skin over the 12th dorsal spine was supplied by the 6th nerve. As a rule, the posterior primary division of the nerve was distributed as far down or further than the anterior branch.

3. This downward sweep of the nerves takes place mainly in their intra- and inter-muscular course. The only mention of the downward course of the nerves in any of the books is contained in Cruveilhier's *Descriptive Anatomy*, vol. i., 1848, p. 1037. He describes with great accuracy the posterior primary division of the 9th, 10th, 11th, and 12th dorsal nerves as passing down between the longissimus dorsi and iliocostalis, but does not mention any obliquity in common with any of the others.

4. The passage of posterior primary divisions of lower dorsal nerves as cutaneous filaments to the buttock—described by Cruveilhier, but not mentioned in any other work—was confirmed as a frequent occurrence, and the opinion expressed that these nerves were frequently demonstrated to students as coming from lumbar nerves only.

5. Great variety existed in the distribution of the posterior primary divisions of the nerves, and they differed much on the two sides of the body. Frequently both the internal and the external divisions gave cutaneous branches.



Fig. 1.

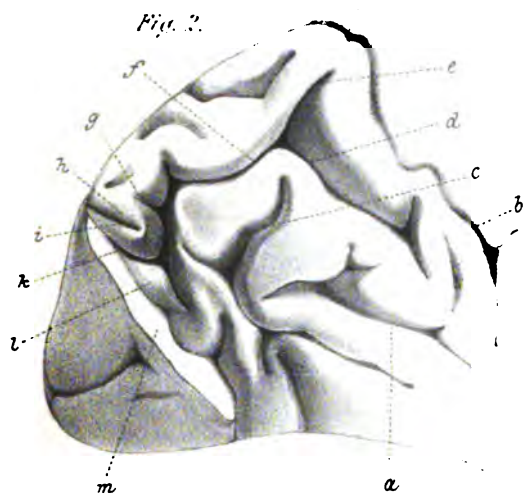


Fig. 2.

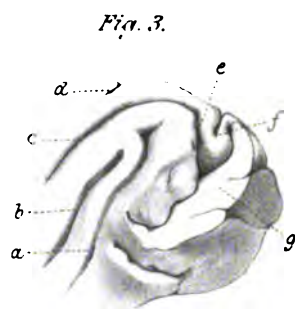


Fig. 3.

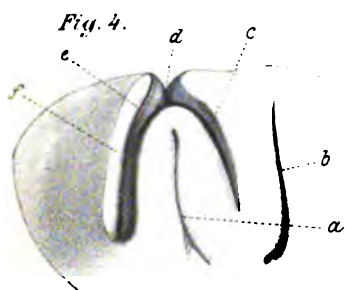


Fig. 4.

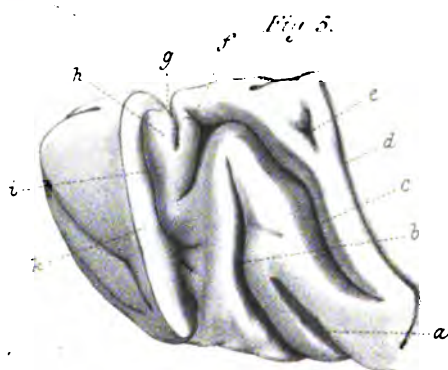


Fig. 5.

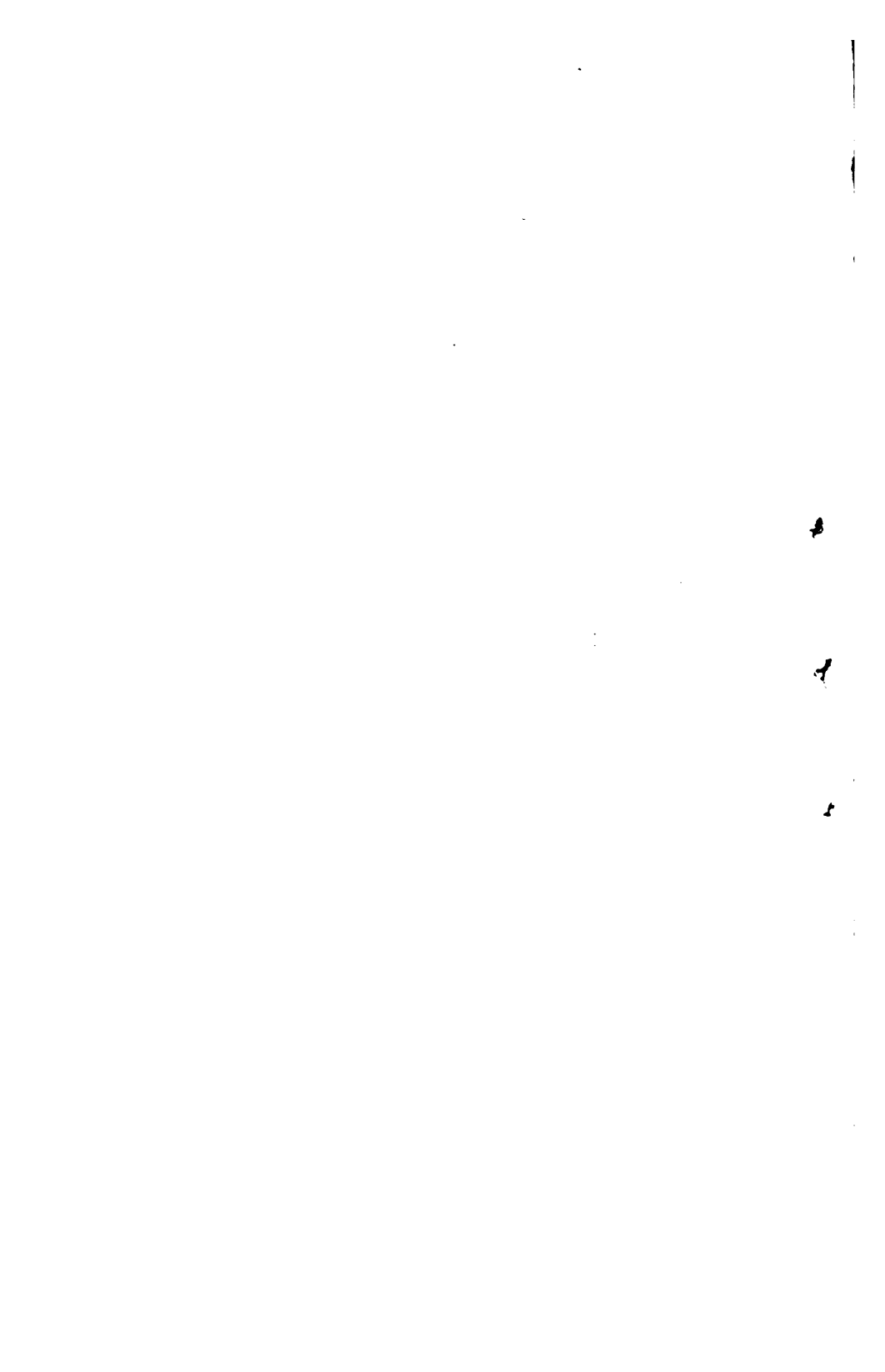


Fig. 1.

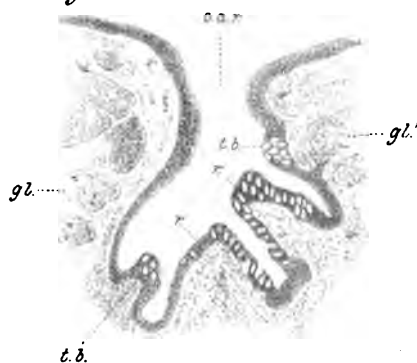


Fig. 2.

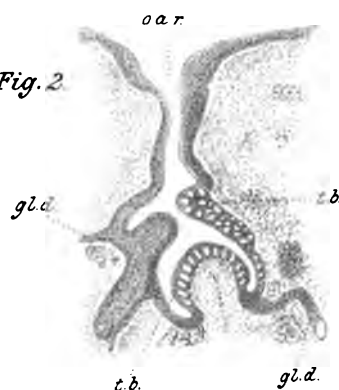


Fig. 3.

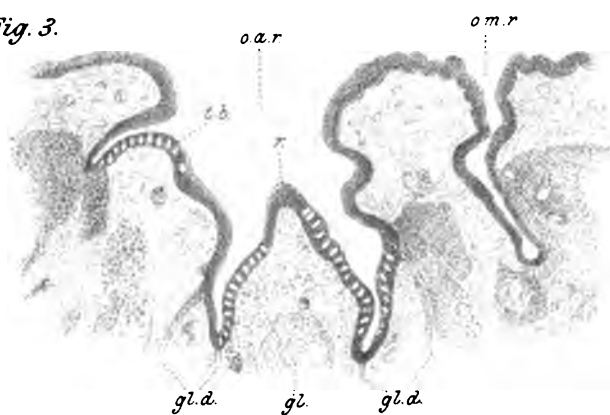
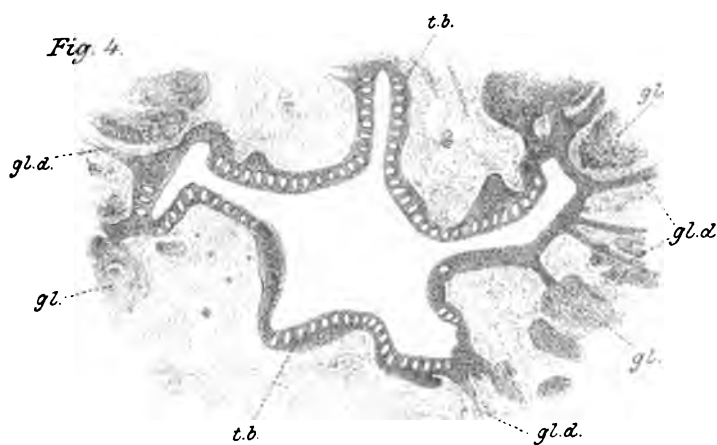


Fig. 4.



GUSTATORY ORGAN.

F. Ruth, Lithr. Edin.

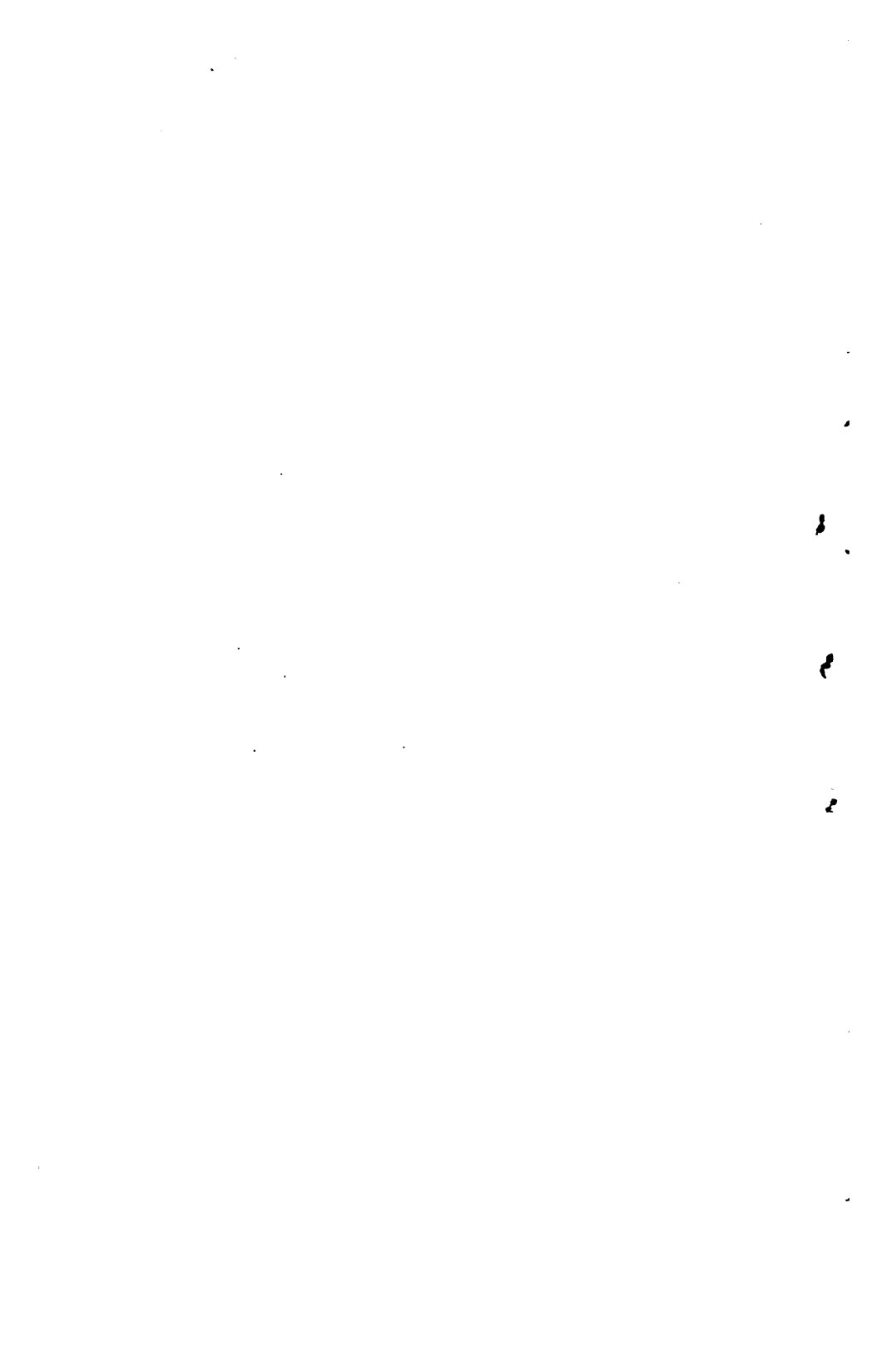




Fig. 1.

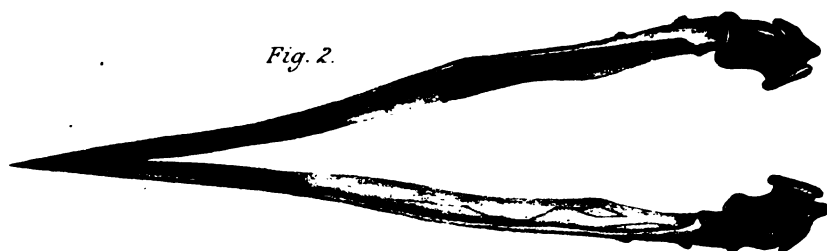


Fig. 2.

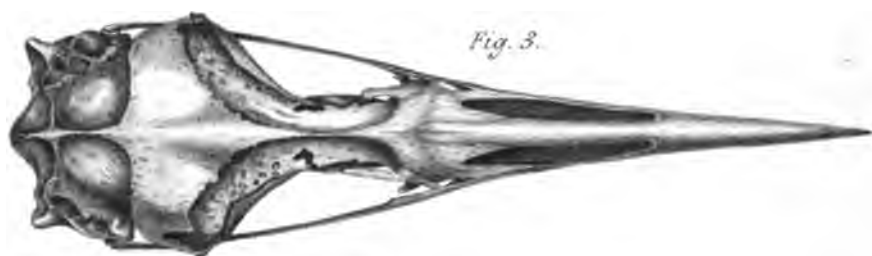


Fig. 3.

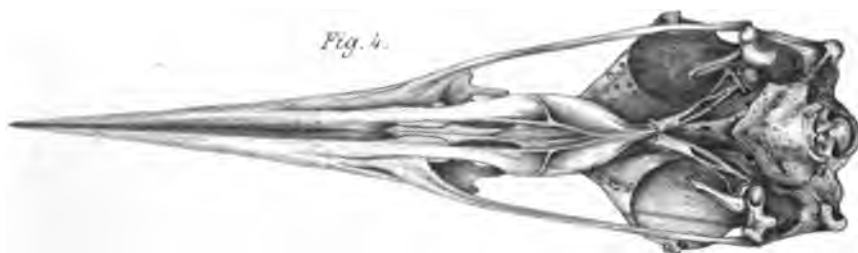
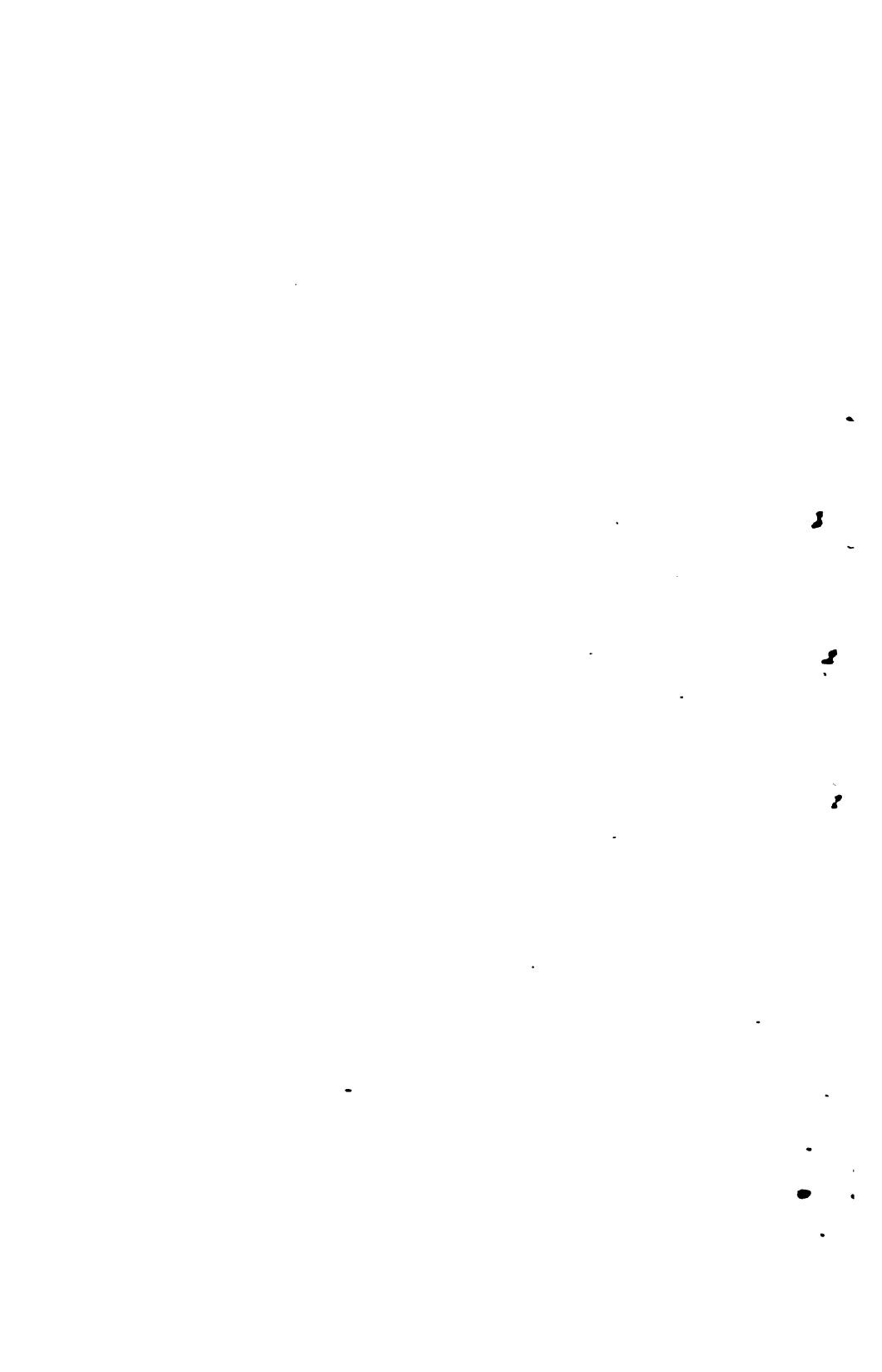


Fig. 4.

H. W. Shufeldt del.

F. Bath Lithr. Edin.

ARCTIC & SUBARCTIC WATERBIRDS.



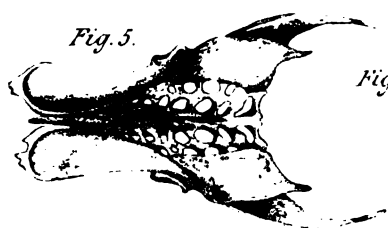
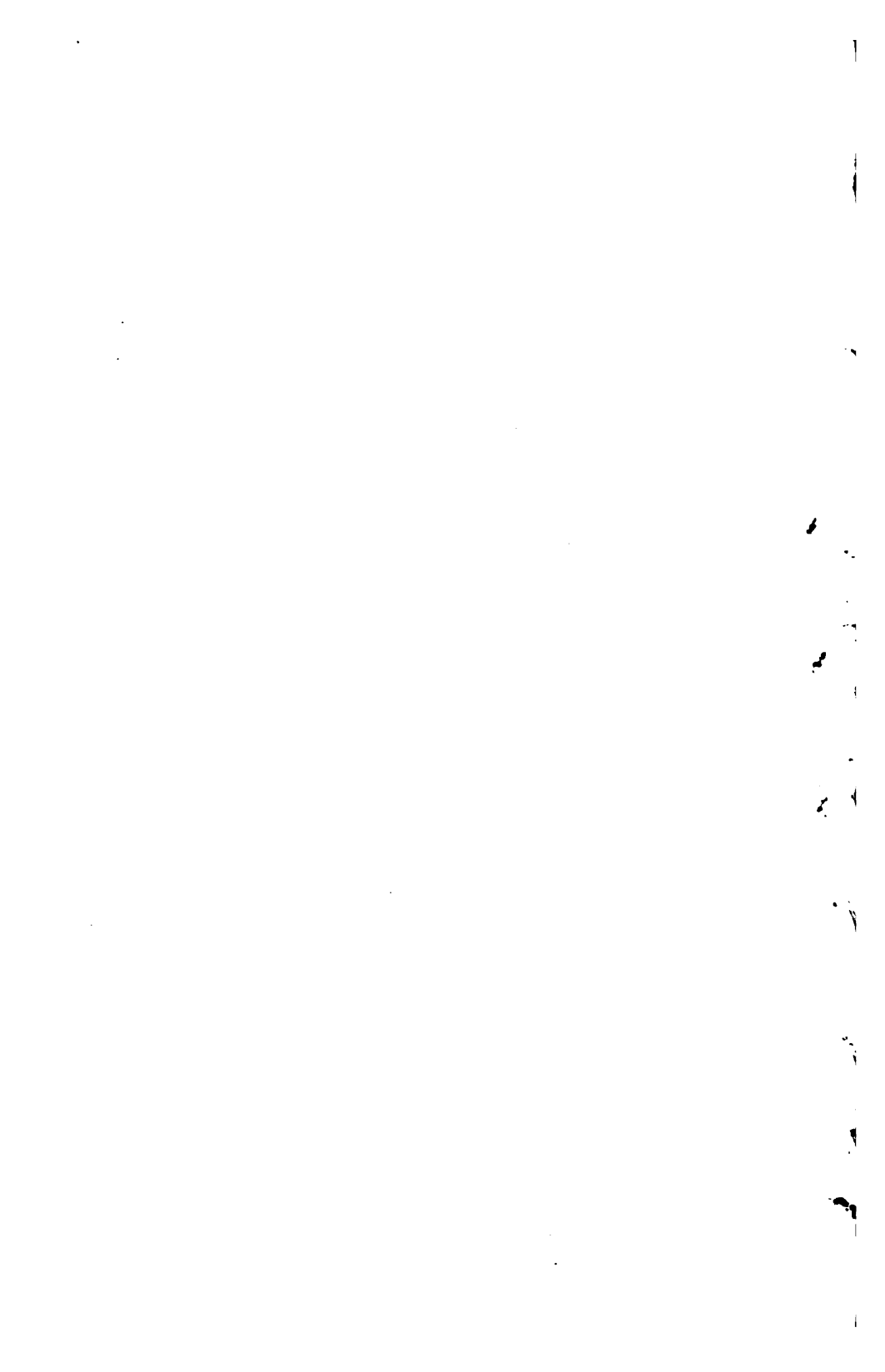


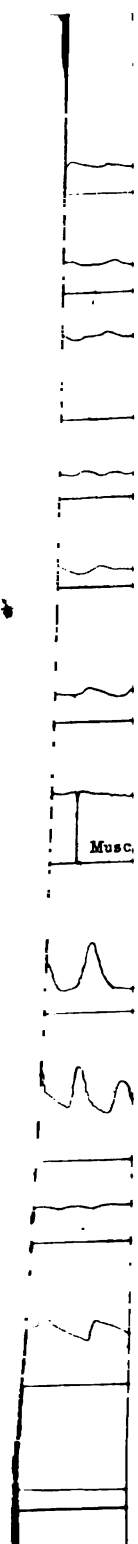
Fig. 8.

Fig. 9.



PLATE XII.





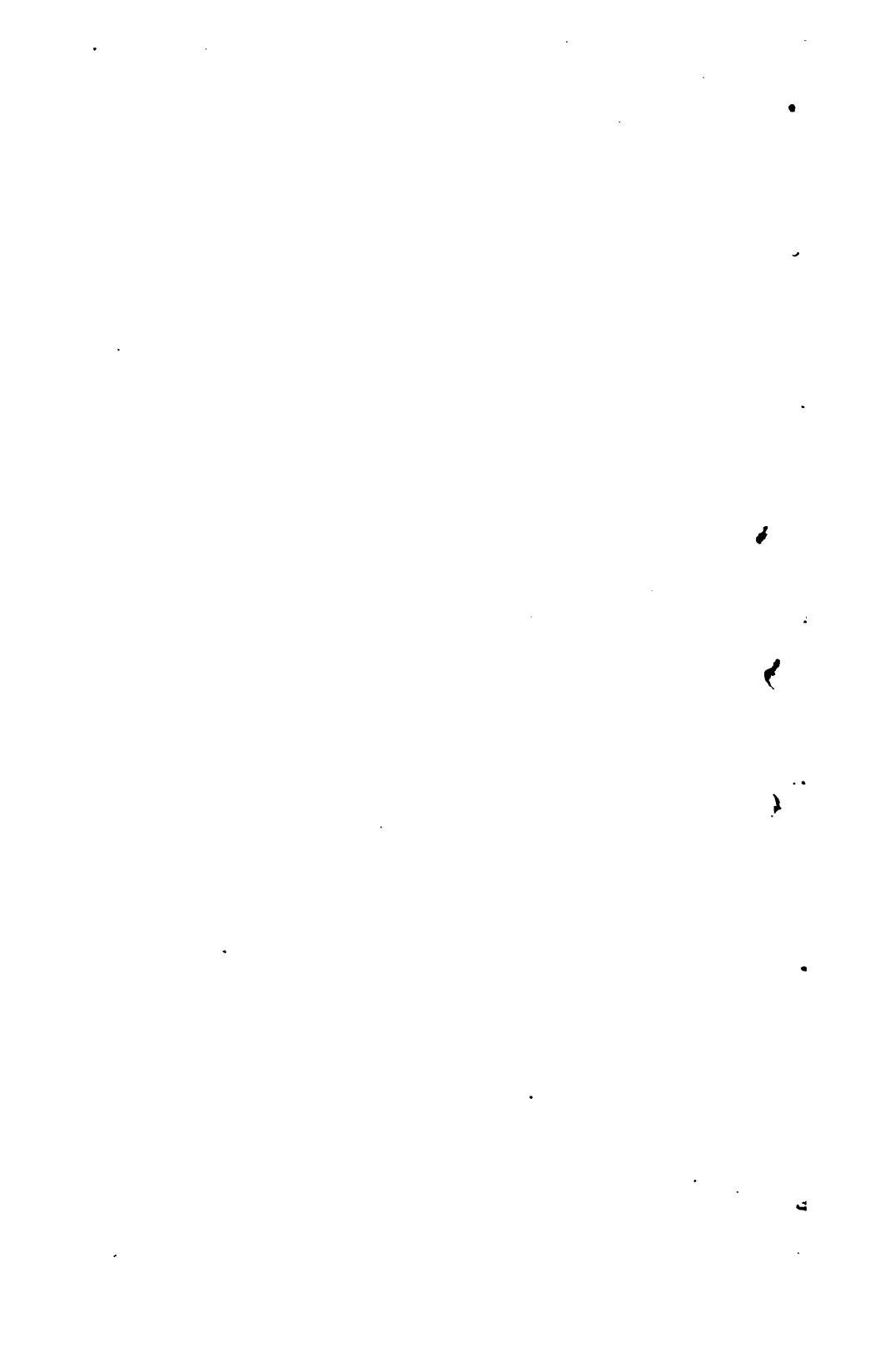


Fig. 1.

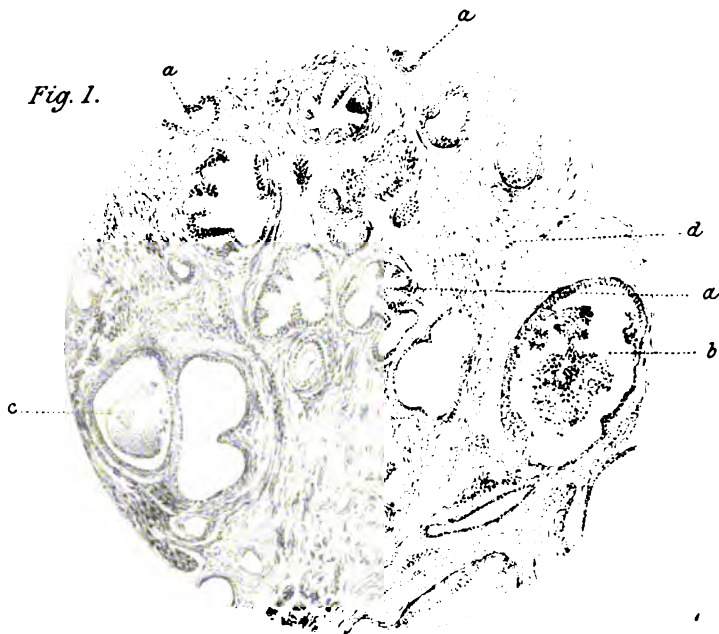
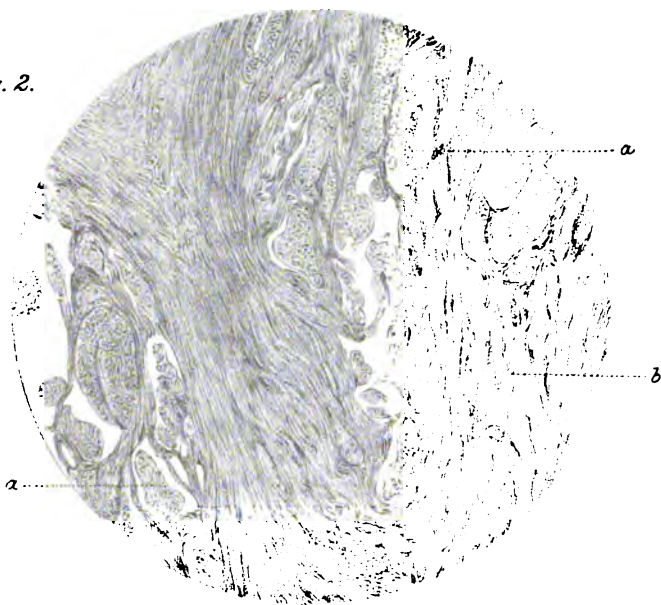
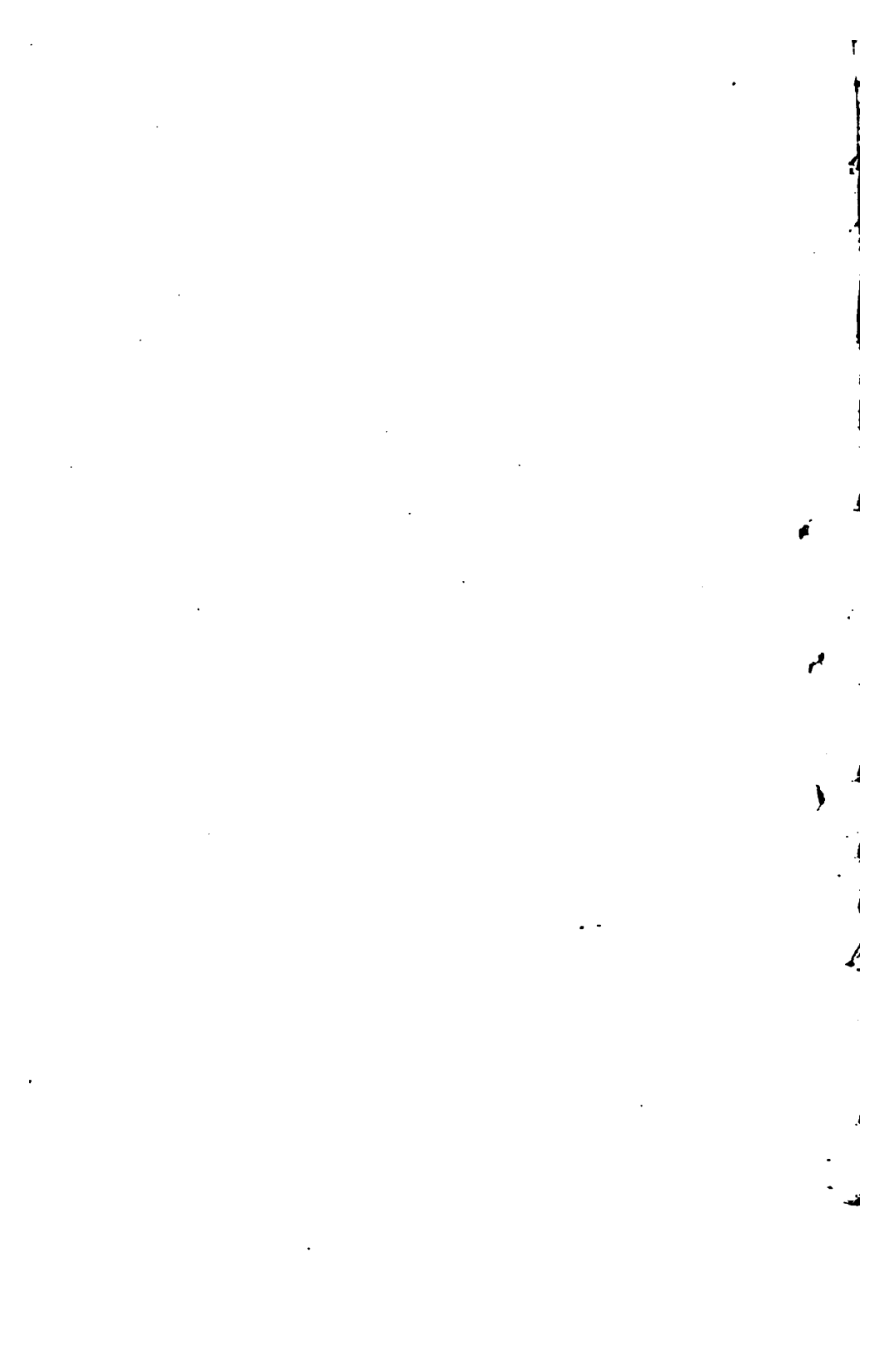


Fig. 2.



F. Huth, Lithr. Edinr.

HYPERTROPHY OF PROSTATE GLAND.



Journal of Anatomy and Physiology.

THE COMPLETE FISSURES OF THE HUMAN CEREBRUM, AND THEIR SIGNIFICANCE IN CONNECTION WITH THE GROWTH OF THE HEMISPHERE AND THE APPEARANCE OF THE OCCIPITAL LOBE. By D. J. CUNNINGHAM, M.D., *Professor of Anatomy in the University of Dublin.*¹

THE complete fissures of the cerebral mantle (the *Totalfalten* of His) appear at an early period in the development of the hemispheres. They are distinguished by the fact that they are the result of a series of deep infoldings of the thin cerebral wall. On the surface of the hemisphere they present a sharply-cut linear appearance. The walls of the different folds are, as a rule, closely applied to each other, and they constitute deep shelf-like projections into the cavity of the primitive lateral ventricle.

The study of these infoldings is a matter of extreme difficulty, because by far the greater number have only a temporary existence. As cerebral growth advances they are obliterated, and the hemisphere surface again becomes smooth. Several, however, occupy positions which later on are occupied by permanent furrows, and either show a direct continuity of existence with these, or at least act as their precursors. It is not surprising, therefore, that very different opinions should be expressed regarding the fate of those primitive infoldings which present this relation to the permanent furrows. More especially do we find the calcarine and parieto-occipital fissures the subject of contending views.

¹ This paper contains the substance of one chapter of a memoir at present in course of preparation, and which will shortly be published by the Royal Irish Academy as "Cunningham Memoir, No. 6: A Contribution to the Anatomy of the Cerebral Hemispheres."

Amongst the "Totalfalten," His¹ includes the fossa Sylvii, but Mihalkovics² rightly denies it a place in this category. The projection into the hemisphere cavity which corresponds with it (viz., the corpus striatum) is not formed by an infolding of the mantle wall, but as an elevation on the floor of the prosencephalon. The surface area corresponding to this internal projection does not keep pace with the mantle as the latter grows around it, and in consequence the Sylvian depression makes its appearance.

It is very questionable if, under ordinary circumstances, any of the complete fissures which appear on the outer face of the embryonic hemisphere are retained as permanent sulci. Later on we shall have occasion to mention two which persist in the Ape, but the corresponding fissures in Man are apparently, as a rule, of a transitory nature.

On the inner or mesial face of the hemisphere, on the other hand, two, or it may be three, of the complete fissures are retained. The conditions of growth here are different. These are more favourable to the appearance of such infoldings, and also more favourable to their retention.

Fissura Arcuata.—Towards the end of the second month of intra-uterine life the fissura arcuata (*Bogenfurche* of Arnold, or *Ammonsfurche* of Mihalkovics) makes its appearance. It pursues a curved course, and cuts off the lower part of the mesial surface of the hemisphere in the form of a semicircular part, which receives the name of arcus marginalis (*Randbogen* of Schmidt). In front the fissura arcuata extends into the frontal region, whilst behind it is carried round towards the extremity of the temporo-sphenoidal lobe. It is in connection with the arcus marginalis or "Randbogen" that the fornix, anterior commissure, corpus callosum, and the septum lucidum are formed. Behind the splenium of the corpus callosum the corresponding part of the arcus marginalis is converted into the gyrus dentatus and the uncus hippocampi. The hind part of the primitive fissura arcuata, which bounds the arcus marginalis, is retained as the hippocampal fissure, and gives rise to the elevation in the floor of the lateral ventricle, which is known

¹ *Unsere Körperform*, Neunter Brief, p. 116.

² *Entwicklungsgeschichte des Gehirns*, 1877.

as the hippocampus major. The fore part of the same fissure is said to be retained as the callosal fissure.

The facts stated above regarding the *fissura arcuata* are well known, and have been carefully and faithfully described by several embryologists. It would appear, however, that the fissure does not always present the simple condition which we have noted. His, who maintains that the inner face of the cerebrum is at no time completely smooth and devoid of furrows, figures the *fissura arcuata* in a ten weeks' foetus,¹ and he represents its hinder end rising upon the mesial face of the hemisphere until it ultimately reaches the upper border. Turning round this, it is continued downwards on the outer surface of the back part of the cerebral mantle. Mihalkovics,² commenting upon this, denies that the *fissura arcuata*, in well-hardened brains ever extends upwards to the free border of the hemisphere.

In a brain in my possession, apparently about the end of the fourth month, or perhaps a week later, an interesting condition of the *fissura arcuata* is present (fig. 2, No. 2, p. 318). In this specimen there is not a trace of the corpus callosum, but the fornix is fully formed in connection with the lower edge of the arcus marginalis, although the two sides have not yet adhered to form the central body-part. The *fissura arcuata* is in two separate portions—a hinder part corresponding in position with the future hippocampal fissure (H.), and a short anterior part (F.A.). This anterior part lies nearer the front than the back end of the cerebrum, and is situated so high up on the mesial surface of the hemisphere that, at first sight, it might be taken for a precursor of the calloso-marginal sulcus. The same condition was present in both hemispheres. On removing the roof of the cerebral vesicle, the fold corresponding to this fissure was seen to project horizontally outwards like a shelf across the greater part of the width of the primitive ventricle (fig. 2, No. 4, p. 318). Its depth may be appreciated by examining the figure, which represents a transverse microscopic section through the fold, as seen under a low power (fig. 3, D., p. 319).

This detachment of the anterior part of the *fissura arcuata* from the posterior hippocampal portion, its reduction in length,

¹ His, *Unsere Körperform*, Leipzig, 1875, p. 113, fig. 112.

² Mihalkovics, *Entwicklungsgeschichte des Gehirns*, Leipzig, 1877, p. 158.

and the similarity which it presents to temporary infoldings in the course of their obliteration, leads me to suppose that in certain cases the posterior hippocampal part of the fissura arcuata alone is retained; or, in other words, that the front part is wiped out, and that the callosal sulcus of the fully-formed brain is a new fissure, which is called into existence at the time when the callosal fibres cross from one hemisphere to the other. To me it is quite unintelligible how His can possibly represent the fornix as being the inner projection arising from the infolding which corresponds to the front part of the fissura arcuata.¹

Certain observers speak very decidedly upon the identity between the front part of the fissura arcuata—(*Bogenfurche*)—and the callosal sulcus. Schwalbe remarks:—"The '*Bogenfurche*,' in its upper part, becomes the upper boundary of the corpus callosum."² Schmidt³ gives expression to a similar view. Were it not for this, I should be inclined to believe that the fore part of the fissura arcuata is obliterated in every case. Unfortunately, Mihalkovics makes no definite statement upon this point, although his drawings would seem to favour a similar conclusion.⁴ Thus in pl. iii. he depicts two brains in which the corpus callosum has not reached its full development, and in these the "*Bogenfurche*" is represented as fading away on the mesial face of the hemisphere, a short distance above the hinder end of that structure.

The calcarine and parieto-occipital fissures would naturally fall to be considered at this stage, but their origin is so closely connected with the appearance of the transitory fissures, that it is more convenient to defer their examination until the latter have been dealt with.

Transitory Fissures (*Vorübergehenden Rinnen* of Schwalbe; *Temporären Furchen* of Ecker; *Vergänglichen Furchen* of Mihalkovics).—These are a series of fissures which appear at an early period upon the cerebral hemisphere in connection with deep infoldings of its thin wall. They are further distinguished by their transitory character. After existing for a period of about two months or more on the mesial wall, and for about two-thirds of that time on the outer wall of the cerebrum, they are, for the most part, finally completely obliterated, and the hemisphere surface becomes smooth. When we come to study

¹ *Unsere Körperform*, Neunter Brief, p. 116.

² *Lehrbuch der Neurologie*, p. 256.

³ "Beiträge zur Entwicklungsgeschichte des Gehirns," *Zeitsch. f. Wiss. Zool.*, 1862, Bd. xii. pp. 54, 55.

⁴ *Entwicklungsgeschichte des Gehirns*, vide pl. iii. figs. 24, 25.

the influences at work in their production, we shall see that they constitute a most suggestive and interesting chapter in the developmental history of the human brain.

It is to J. F. Meckel that the credit is due of having, in the first instance, recognised these transitory fissures. In 1815 he published a paper in which he remarks:¹—"Although I find the brain in the six to the seven weeks' embryo completely smooth, the very thin walls of the lateral ventricles appear to shape themselves into extremely numerous and deep convolutions and furrows from the eighth to the ninth week." He asserts that the fissures are due to deep infoldings of the hemisphere wall, and is at considerable pains to prove that the condition is not produced by the shrinkage brought about by the hardening reagent. He therefore holds "that these convolutions are primitive formations, and are essentially a part of the development of the brain." His account of the manner in which these early infoldings of the hemisphere wall disappear is of some interest. We shall use his own words:—"But upon this period another supervenes in which these convolutions, as well as their outer and inner surfaces, grow into each other, so that the surface of the brain, both inside and outside, again becomes smooth." And he considers that this process of obliteration may be regarded as affording a means by which the wall of the ventricle is thickened, and also by which the white substance is increased in quantity.

In the following year (1816) Friedrich Tiedemann² also refers to these primitive transitory furrows, but he falls into the error of supposing that they represent the earlier conditions of the permanent sulci.

Schmidt³ in 1862 figured them for the first time, and he clearly recognised their temporary nature. One point of importance, he adds, viz., that although he has failed to discover them in the embryos of the Sheep, Ox, and Pig, he believes that he has seen faint traces of them in the brain of the early Cat embryo.

Ecker,⁴ His,⁵ and Mihalkovics,⁶ and other German authors have likewise taken notice of the temporary furrows, although they have, as a rule, dealt with them briefly, and have not made a serious attempt to unravel the part which they play in the process of brain development. It is but right to mention, however, that Richter⁷ has

¹ *Deutsches Archiv f. Physiol.*, Halle and Berlin, Bd. i. 1815.

² *Anatomie und Bildungsgeschichte des Gehirns im Fetus des Menschen*, Nürnberg, 1816.

³ "Beiträge zur Entwicklungsgeschichte des Gehirns," *Zeitsch. f. Wiss. Zool.*, Bd. xi.

⁴ "Zur Entwicklungsgeschichte der Furchen und Windungen der Grosshirn-hemisphären im Fetus des Menschen," *Archiv f. Anthropol.*, Dritter Band, Drittes und Viertes Heft, 1869.

⁵ *Unsere Körperform*, Leipzig, 1875.

⁶ *Entwicklungsgeschichte des Gehirns*, 1877.

⁷ "Ueber die Entstehung der Grosshirnwindungen," *Virchow's Archiv*, Berlin, 1887.

given a very admirable account of the fissures in question, and has added considerably to our knowledge regarding them.

It is somewhat curious that Bischoff, writing as late as 1868, should have cast doubts upon the reality of the transitory furrows. He asserts that all previous observations in this direction are founded upon an error, and that the fissures in question are produced artificially by the action of the alcohol in which the brains have been immersed. He further maintains that in specimens treated with chloride of zinc the surface of the hemisphere remains perfectly smooth up to the time of the appearance of the permanent sulci. Ecker disposes of this objection by the statement that he has observed the transitory furrows in the brain of a third-month embryo which was examined in the fresh condition.

In Italy Giacomini,¹ Romiti,² and Mingazzini³ have paid some attention to the temporary fissures, but in this country little or no notice has been taken of them. It is true that Callender in his "Lectures upon the formation and early growth of the Brain of Man,"⁴ has referred to them, but his systematic neglect of the work done by others in the same field greatly diminishes the value of his observations.

The material which I have had at my disposal for observing the characters and tracing the history of the temporary fissures has not been so abundant as I might have desired. I only possess the brains of three embryos which come within the limits of the prescribed period, viz., one a little over the third month, and two which I take to be slightly over the fourth month. But in addition to these I have been allowed in the most generous manner to handle, describe, and photograph four very characteristic specimens in the museum of the University College of London. These range from the middle of the third month up to near the end of the fourth month or thereabouts. Further, Professor Victor Horsley has been so kind as to furnish me with a beautiful series of photographs of the fetal brain preparations which are displayed in the museum of the University of Oxford. One of these from an embryo approaching the fourth month is especially characteristic (fig. 5, Nos. 4 and 5, p. 322). The figures which are given by Schmidt, v. Kölliker, and

¹ *Guida allo studio delle circonvoluzioni cerebrali dell' uomo*, Torino, 1884.

² "Sull' ordine di successione, con il quale appaiono le scissure cerebrali," *Processo Verbale della Soc. Toscana di Sci. Nat.*, 1882.

³ "Ueber die Entwicklung der Furchen und Windungen des Menschlichen Gehirns," *Untersuchungen zur Naturlehre des Menschen und der Thiere*, herausgegeben von Jac. Moleschott, xiii. Band, 6 Heft.

⁴ *British Medical Journal*, June 6, 1874.

Richter I have also found useful, although those which we commonly see in our text-books, and which have been taken from Ecker and Mihalkovics, cannot be regarded as giving a proper idea of the transitory furrows as they exist during the period of their maximum development.

Duration of the Transitory Fissures.—The mesial wall of the hemisphere is considerably thinner than the outer wall, and it is partly in consequence of this that the transitory fissural infoldings first make their appearance upon it. But we have the most conflicting statements regarding the actual period at which they first begin to be formed, and also regarding the time at which they vanish. These views will best be understood if I place them in tabular form :—

Duration of Transitory Furrows.

Authority.	Period of Appearance.	Period of Obliteration.
Meckel.	8th to the 9th week.	.....
Schmidt.	Middle of the 3rd month.	End of the 4th month.
Ecker.	3rd to the 4th month.	Commencement of the 5th month.
v. Kölliker. ¹	3d month.	5th month.
Mihalkovics.	Middle of the 3rd month.	Commencement of the 4th month.
Romiti.	10th week.	End of the 4th month.

We may remark here that the description given by Schmidt hardly agrees with his figures, because the transitory fissures are indicated by him on the mesial surface of a cerebrum taken from an embryo at the eighth week, which bears out the original observation of Meckel.

The difference of opinion which is shown in the above table results no doubt very largely from variations in the duration of these fissures, but it is likely that it is also in a great measure due to the almost insuperable difficulty of giving to an embryo its proper age. As I have stated, the embryos which I have specially studied with the view of obtaining a knowledge of the transitory fissures ranged from about the third month to about the end of the fourth month. In all of these the transitory fissures were visible. Clearly Mihalkovics is wrong in limiting the time of their existence to one fortnight. It appears equally

¹ *Entwicklungsgeschichte des Menschen und der höheren Thiere.*, 1870.

certain that they may begin on the mesial face of the hemisphere as early as the eighth week. Meckel has told us so, and Schmidt has figured them at this stage; but they do not attain, even on this aspect of the hemisphere, a high degree of development until the ninth or tenth week.

On the outer surface of the hemisphere their formation is delayed. It is doubtful if they ever show on this aspect before the tenth week. In most cases they attain their maximum degree of development between the third and fourth months, and this holds good for both surfaces of the hemisphere.

A certain amount of latitude must also be allowed in reckoning their time of disappearance; but as a rule it will be found that they become obliterated between the periods at which the fornix and corpus callosum become developed; in other words somewhere towards the end of the fourth month. From this general statement, however, we must make an exception in favour of two fissures which appear on the outer aspect of the occipital lobe, and whose history I purpose discussing at some length further on.

Transitory Fissures on Medial Wall of Hemisphere.—As a general rule, the transitory fissures on the mesial wall of the hemisphere are very definite in their relations, although they vary greatly in number. They consist of a series of furrows which radiate in a stellate manner from the fissura arcuata

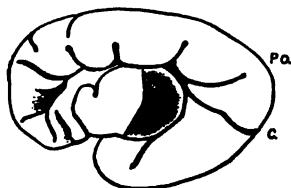


FIG 1.—Mesial surface of the right hemisphere of a fetus about the twelfth week, or a little later. P.O, the precursor of the parieto-occipital fissure; C, the precursor of the calcarine fissure.

(*Bogenfurche*) towards the free border of the hemisphere. At first they appear as a number of notches or indentations in the upper boundary of the fissura arcuata. These are shallow and broad at the base, and they give to the medial cerebral wall a wrinkled or crumpled appearance. At this stage they might very readily be mistaken for depressions brought about by the

shrinkage caused by a hardening reagent. After a while they deepen and lengthen out, and they may extend as a continuous series all the way round from the frontal pole in front to the extremity of the temporo-sphenoidal lobe below (fig. 1). The majority of the transitory fissures on the medial face of the hemisphere do not reach so far as the border of the hemisphere, but two at the occipital or postero-superior pole, very constant in position and longer than the others, almost invariably do so; and, occasionally, in the frontal region and at the end of the temporal lobe one or more may also show a similar extension.

As we have stated the number of radiating temporary fissures on the medial aspect of the hemisphere varies very greatly. In one cerebral hemisphere Richter counted nine, and in another only five. The number is usually the same, or approximately so, on the two hemispheres of the same brain, and the usual number seems to be eight. Eight hemispheres, all between the third and fourth months, yielded the following results in this respect:—

In <i>four</i> the number was,	.	.	.	.	8
„ <i>two</i> „ „	.	.	.	.	6
„ <i>one</i> „ „	.	.	.	.	9
„ <i>one</i> „ „	.	.	.	.	5

No doubt the difference in the number of fissures on the medial surface is partly due to the different periods of development at which the brains were examined, but I do not believe that this is the only factor present in determining the variations. The influence at work in calling the infoldings of the cerebral wall into existence appears to be a purely mechanical one, viz., a restraint placed upon the longitudinal growth of the hemisphere, and this being the case it is easy to understand how the number and depth of the fissures will vary with the degree and kind of restraint which is applied.

Primitive Cuneate Subdivisions of the Medial Hemisphere Wall.—By the presence of the stellate fissures, when they are developed in a marked form, the medial surface of the hemisphere outside the fissura arcuata is subdivided into a number of wedge-shaped or cuneate portions. That portion which intervenes between the two long fissures, which we have mentioned

as being always present on the occipital part of the hemisphere, is retained as the cuneus of the adult brain. The other portions in front of this region, and also those below it, again run into each other when their bounding fissures are obliterated, and they then form the smooth tracts out of which the gryus fornicatus, calloso-marginal convolution, precuneus, and the convolutions on the under surface of the occipital and temporal lobes are ultimately formed. The primitive fissures which bound the cuneus proper are the precursors of the calcarine and parieto-occipital fissures.

Obliteration of the Transitory Fissures.—To study in all its details the manner in which these transitory fissures disappear and vanish from the mesial surface of the hemisphere, so as not to leave a single trace of their former existence, either on the outside or inside of the cerebral wall, would require a greater number of specimens, and these more varied as to the term of

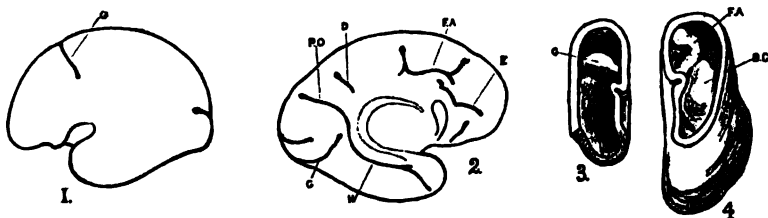


FIG. 2.—A series of views of the cerebrum of a fetus about the end of the fourth month, or a little later. No. 1, outer surface of the left hemisphere. No. 2, mesial surface of the left hemisphere; E. and D, detached radial fissures; F.A., anterior detached part of the fissura arcuata; H, hippocampal fissure; C, precursor of the calcarine fissure; P.O., parieto-occipital fissure. No. 3, the roof of the right hemisphere removed and turned so as to expose its ventricular aspect; G, the infolding corresponding to the fissure marked by the same letter in No. 1. No. 4, the left hemisphere with the roof removed; F.A., the infolding corresponding to the anterior detached part of the fissura arcuata.

their development than those which I possess. Still in the material at my disposal a number of interesting points may be determined. As the wall of the cerebral vesicle thickens and the hemisphere elongates one or more become detached from the fissura arcuata (fig. 2, No. 2, D.). They then appear as isolated short fissures. These continue to decrease in length until they appear as little more than a point, corresponding

with which a small rounded elevation is seen on the inner aspect of the wall of the ventricular cavity. Finally, this disappears also, and both aspects of the wall become smooth. Although I have observed the detachment of the fissures from the fissura arcuata on the medial aspect of the hemisphere, I have not been able to follow the subsequent stages of obliteration. On the outer wall of the hemisphere, however, these stages can be easily traced, and in fig. 12 (No. 3, E.C., p. 337) the rounded ventricular elevation, the remains of an inward fold, may be seen.

But, as we have previously mentioned, the fissura arcuata itself may break up (fig. 2, No. 2). In all cases the posterior hippocampal portion (H) is preserved *in situ*, and, in connec-

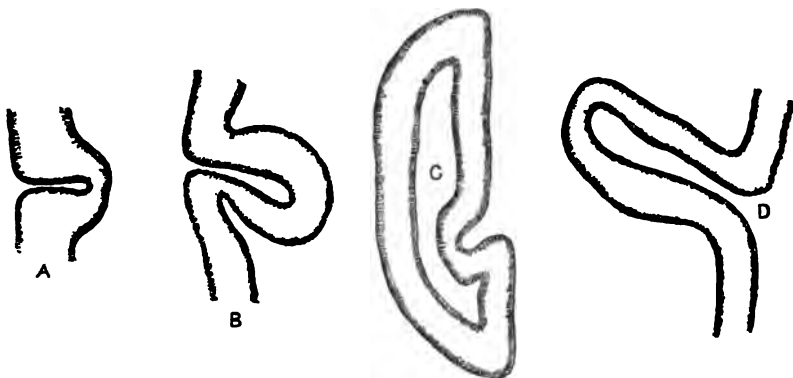


FIG. 3.—Microscopical sections through certain of the infoldings of the right hemisphere, which is depicted in fig. 2, viz., Nos. 2 and 3. A, section through the upper part of the infolding marked G in fig. 2; B, section through the middle of the same infolding; C, section through the anterior part of the same cerebral hemisphere, showing the anterior detached radial infolding which is marked E in fig. 2; D, section through detached anterior part of the fissura arcuata.

tion with this, the precursors of the calcarine and parieto-occipital fissures may remain attached. The anterior part (F.A.), with whatever radial fissures still adhere to it, assumes a more elevated position on the mesial wall of the hemisphere; and I have already given expression to the view that it also may become obliterated. Whether this is the usual course of development or not I cannot say, as I only possess one brain in which the process is seen. The left hemisphere of this specimen

is represented in fig. 2. Two isolated radial fissures are seen in course of obliteration—one on the inner face of the frontal lobe (E.), and the other (D.) a short distance in front of the precursor of the parieto-occipital fissure. The hippocampal fissure, with the precursory calcarine and parieto-occipital furrows are very evident (H.; C.; and P.O.). The anterior part of the fissura arcuata is greatly shortened; it has two radial furrows in connection with it, and it has broken away completely from the hippocampal fissure, and presents all the appearances of being in process of obliteration. The right hemisphere of the same brain showed a condition almost identical with that of the left side. Fig. 2, Nos. 3 and 4, gives a view of this hemisphere with the roof removed. The deep infolding caused by the anterior part of the fissura arcuata is seen stretching outwards upon the floor of the ventricle. In figure 3 (C) a transverse microscopical section through the fore part of the hemisphere is exhibited, as seen under a low magnifying power. The infolding corresponding to the anterior detached radial fissure (fig. 2, No. 2, E.) is seen. In the same figure (D.) a similar transverse section through the front detached part of the fissura arcuata is depicted. The depth of this infolding is very remarkable.

Transitory Fissures on the Outer Surface of the Hemisphere.—The transitory fissures are not, as a rule, disposed so

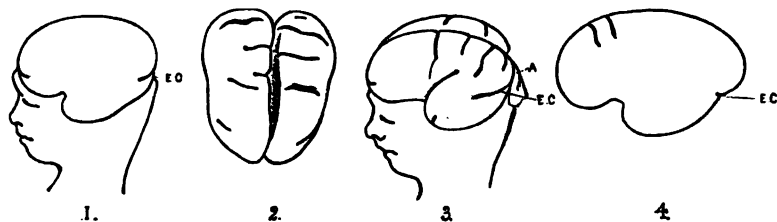


FIG. 4.—No 1, right hemisphere of a fetus about the eleventh week. Nos. 2 and 3, different views of a fetal brain between the thirteenth and fourteenth week. No. 4, left hemisphere of a fetus about the end of the twelfth week, or a little later; E.C., precursor of the external calcarine.

uniformly on the outer face of the hemisphere as they are upon the medial face. They show a tendency, however, to assume a similar arrangement. Starting from the free border of the hemisphere, they run in a convergent manner towards the

Sylvian region, or, in other words, towards the hilum of the bean-shaped cerebrum; but in all cases they fall short of this. In well-marked cases they are present all the way round the mantle border from the frontal pole in front to the temporo-sphenoidal pole below. At some particular part of the circumference it is usual to see them more concentrated or more closely placed and more numerous than elsewhere. In certain cases this may occur in the frontal region (fig. 4, No. 4, and fig. 5, Nos. 2 and 4); in other instances it is in the parietal region that the crowding together takes place (fig. 4, Nos. 2 and 3).

But the fissures have not always the simple and uniform arrangement described above. With these, others are usually associated. Thus, it is by no means uncommon to see a fissure occupying a position and possessing a direction similar to that of the adult Sylvian fissure (fig. 5, Nos. 1, 2, 3, and 4; also fig. 4, No. 3, &c.). In eight hemispheres examined this was present in five instances, and it was no mere superficial furrow, but a deep cleft, which separated the upper and front part of the cerebrum from the lower and back portion almost as effectually as the clefts of the lung separate its various lobes. Altogether this is a most striking infolding. It is seen in great perfection in one of the specimens displayed in the museum of the University College, London (fig. 5, Nos. 1, 2, 3). All the brains in which it occurred I reckoned to be about the same period of development, viz., from the thirteenth to the fourteenth week. In brains younger than this (fig. 4, No. 1), or older (fig. 4, No. 4, and fig. 2, No. 1), there is not a trace of it. At the same time, I am not prepared to say that this remarkable fissure is always present. It is clear, however, that there is a marked tendency towards the formation of such a fissure under certain conditions of growth-restraint, and that these conditions appear to be usually present. It is further apparent that the presence of such an infolding in this locality must influence the development of the fossa Sylvii. This aspect of the question I purpose postponing for future consideration, seeing that at present we are merely engaged with the study of the complete fissures, and the Sylvian fossa does not fall within this group.

In one hemisphere a second deep cleft was present, below and parallel to that just described. It therefore occupied the ground

of the future parallel sulcus of the more fully-developed brain (fig. 5, No. 3, B.); but, whilst this is the case, I would not for a moment hint that it has anything to do with the development of the adult sulcus of that name.

Again, it is by no means unusual to observe short isolated fissures removed a short distance from the free border of the hemisphere. They are, doubtless, fissures in process of obliteration. They are chiefly to be noticed in specimens between the third and the fourth month (fig. 4, No. 2, and fig. 5, Nos. 3 and 4).

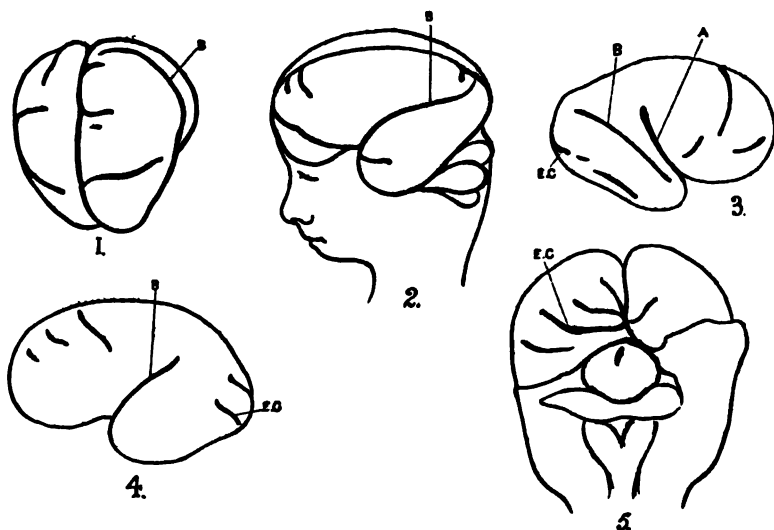


FIG 5.—Series of cerebral hemispheres between the thirteenth or fourteenth week of development; E.C., external calcarine; A, deep infolding in position of Sylvian fissure; B, another in position of the future parallel fissure.

In certain hemispheres the fissure on the mesial face, which we have named, provisionally, the precursor of the calcarine fissure, is carried horizontally round the occipital pole, cutting it deeply, and appearing on the outer surface in the form of a fissure, which we may term the *external calcarine* (fig. 5, No. 5, E.C.). This fissure has a most interesting history, which I purpose tracing at a later stage of this paper. In the meantime, I may merely call attention to the fact that this external calcarine fissure was present in the great majority of the hemi-

spheres examined, although it was not, in every case, continued round the occipital pole into the precursor of the calcarine fissure on the medial face of the cerebrum (figs. 2, 4, and 5, E.C.).

In figure 4 (No. 1) the left hemisphere of an embryo at about the eleventh week is represented. Two short fissures—one in front and the other behind—are alone present on the outer surface of the cerebrum. Between these, however, the cerebral mantle is faintly streaked by a series of faint grooves, which present very much the direction of the transitory fissures when fully developed. Most likely these markings indicate the initial stages in the formation of the fissures. When fully formed, a deep infolding is the result. Figure 3 (B.) shows a transverse microscopical section through the middle of the fissure indicated in the frontal region of the brain depicted in figure 2, No. 3, A. The lips of the furrow are closely applied to each other at the surface, and it is this that gives to such fissures their sharply-cut linear appearance; but, towards the bottom of the sulcus, the walls of the fold are separated to a small extent, and a slight recess is formed between them. Schmidt has stated that, at the places where the bending-in of the cerebral wall takes place, the wall of the hemisphere is thinner than elsewhere. This is well seen in figure 3 (B.), although on the one side of the fissure it is better marked than on the other. At the same time it must be noted that this condition is not universally present. In the shallow parts of a fissure, or where a fissure is shallow throughout, it is the bottom of the fold that becomes thinned (fig. 3, A. and C.). When a continuous series of sections is made through the entire length of one of the transitory fissures the central part is seen to be very deep (fig. 3, B.), while at its two extremities it is shallow, and the bottom gradually rises to the surface (fig. 3, A.). The folds, therefore, as seen from the ventricular aspect, present a semilunar form (fig. 2, No. 3, A.).

A study of the various specimens would seem to indicate that the process of obliteration consists in a shortening of the fissure from both extremities towards the centre. More and more of the bottom of the furrow rises to the surface, until at last the deep central part alone remains in the form of a round knob-like elevation on the ventricular aspect of the wall (fig. 10, Nos. 3 and

4, E.C.). Ultimately this disappears also. During this process the fissures retreat from the hemisphere margin, and in several of the figures which are given (fig. 4, No. 2, and fig. 5, Nos. 3 and 4), one or more of these may be observed. But it is necessary to mention here what we shall have to insist upon more fully hereafter, viz., that this obliteration does not appear to depend solely upon a process of unfolding, but that a certain amount of absorption of the fold appears also to take place.

On the outer surface of the hemisphere, just as on the mesial surface, the number of transitory fissures present varies very considerably. Ten hemispheres of embryos, ranging from the tenth week or so up to the end of the fourth month, gave the following results:—

In *none* was the outer surface smooth.

„ 4 there were 8 fissures.

„ 1 „ „ 7 „

„ 1 „ „ 5 „

„ 1 „ „ 4 „

„ 2 „ „ 3 „

„ 1 „ „ 2 „

It is interesting to note that the number most commonly present was eight, just as in the case of the mesial surface.

In only one brain were the fissures arranged absolutely symmetrically on the two hemispheres. This was, perhaps, the most instructive specimen of the series, and several views of it are given in fig. 2, p. 318. Although not disposed in the other brains in exactly the same way on the two sides, there was always noticed a general correspondence between the two hemispheres in the number and character of the fissures. Thus, two of the hemispheres in which eight fissures occurred belonged to the same embryo, whilst in another case there were eight on the one side and seven on the other.

A very interesting question arises at this point—Do circumstances ever arise under which these transitory fissures of the early cerebrum are retained permanently? There is good reason to believe that in many cases those we have named the precursors of the parieto-occipital and calcarine show an unbroken continuity of existence with the fissures which bear the same

name in the fully-developed brain. Further, the corresponding fissures on the outer face of the occipital lobe (external perpendicular of Bischoff and external calcarine), in rare instances, may also be preserved. Certainly they always enjoy a much more prolonged existence than the other transitory fissures. Lastly, there cannot be a doubt that in certain malformations of the brain, as, for example, absence or defective formation of the corpus callosum, this primitive and, under normal circumstances, transitory fissural system is in a measure preserved. Anton¹ is of opinion that the disappearance of the transitory furrows is largely due to the development of the corpus callosum. It is no doubt true that the obliteration is very nearly synchronous with this, but whether it is caused by it is altogether another matter.

Recently Dr Alexander Bruce has published in the *Proceedings of the Royal Society of Edinburgh* (vol. xv.) a very able paper upon a case of congenital absence of the corpus callosum. The admirable drawing which he gives of the inner face of the cerebrum is most suggestive. There is not a trace of the calloso-marginal fissure, but, radiating from the fissura arcuata towards the free border of the hemisphere, there are a number of diverging sulci. These are undoubtedly to be regarded as the primitive and usually transitory fissures which are always present on the mesial face of the hemisphere during its early stages of development, and which in this case have been preserved. Equally instructive are the figures given by other authors of this face of the cerebral hemisphere in brains with no corpus callosum. Those of Eichler,² Knox,³ and more especially of Onufrowicz,⁴ show the retention of the transitory fissural arrangement in the most marked manner.

But it is not on the inner surface alone that the transitory fissures may be retained. Hans Virchow⁵ has described and figured a very extraordinary brain, in which the corpus callosum was absent in connection with hydrocephalus internus. The fissural type (fig. 6) on both aspects of the cerebral hemisphere is that of the period of the transitory fissures. With reference to those on the outer surface, he remarks:—"Ebenso auffallend ist die Abweichung vom Typus bei den Furchen. Es ist gewissermassen der normale Typus gänzlich aufgehoben und durch einen neuen Typus ersetzt, welcher an die

¹ *Zeits. für Heilkunde*, Band vii., 1886.

² *Archiv f. Psychiatrie*, vol. viii. pt. 2, 1878.

³ *Glasgow Medical Journal*, 1885.

⁴ *Archiv f. Psychiatrie*, vol. xviii., 1887.

⁵ "Ein Fall von angeborenem Hydrocephalus internus, zugleich ein Beitrag zur Mikrocephalen Frage," v. Kölliker's *Festschrift*, 1887, Leipzig, p. 305.

Zustände beim ersten Auftreten der Furchen dadurch erinnert, dass eine Tendenz zu radiären Anordnung die Furchen beherrscht." But it is not a persistence of the "radiären Primärfurchen" of Reichert,¹ Bischoff,² and Pansch³ that this brain shows, but the retention of the much earlier transitory fissures.



FIG. 6.

In Dr Bruce's case of absent corpus callosum, the fissure of Rolando was situated very far forward, and was continued over the upper border of the cerebrum on to the mesial face of the hemisphere. We might naturally question, therefore, whether or not it was the true fissure of Rolando or merely a furrow produced by the retention of one of the primitive transitory fissures. Such a fissure as is represented in figure 2 (No. 1, g.) would stand for it. The direction of the Rolandic fissure in Dr Bruce's case—viz., from above downwards and backwards—would lend some support to this view.

In speaking of the disposition of the fissures on the mesial face of the cerebrum in his specimen of absent corpus callosum, Dr Bruce remarks:—

"The radiated convolutionary arrangement is very difficult to explain. It may be due to the mechanical resistance offered by the ring-like marginal arch to the growth of the grey matter of the gyri. This will thus become furrowed, much as a bag made of cloth when a string is tied tightly round its neck. In this case, too, the furrows radiate outwards from the string. The abnormal mesial fissure of Rolando is not found in other cases. I am at a loss to account for it, except on the view that the forward growth of the brain has surpassed that of the cranium, and that a duplicature of the inner surface was thus produced." This is a most ingenious explanation, and may in part be applied to the production of the primitive furrows on the inner aspect of the hemisphere in the early stages of normal brain-growth.

¹ *Der Bau des Menschlichen Gehirns*, Leipzig, 1861.

² "Die Grosshirnwindungen des Menschen," *Abhandl. der k. bayer Akad. der Wiss.*, 11 Cl. x Bd. 11 Abth.

³ "Ueber die typische Anordnung der Furchen und Windungen auf den Grosshirnhemisphären des Menschen und der Affen," *Archiv f. Anthropol.*, Dritte Band, Drittes und Viertes Heft, 1869.

Parieto-occipital and Calcarine Fissures.—The views which have been advanced by different authors regarding the origin of the parieto-occipital and calcarine fissures are very conflicting, and no doubt there are many points in connection with their first appearance and history which are extremely puzzling.

v. Kölliker¹ maintains that they appear synchronous with the temporary fissures on the mesial aspect of the hemisphere, and constitute members of the same series—differing from them only in so far that they are permanent and not evanescent. He says:—"As early as the separation of the frontal lobe from the temporal lobe by the Sylvian fossa there arises a boundary for the occipital lobe by the appearance of the parieto-occipital fissure. This is distinct in the third month. Schmidt even figures it in the eighth week." Richter,² who gives a good account of the transitory furrows in a series of early embryos, appears to entertain the same view. Referring to a brain with hemispheres 3·3 c.m. long, he remarks:—"An der medialen Seite der Hemisphären gingen einige radiäre Falten mehr von der Bogenfurche aus als bei Fötus 3. Bei letzterem zählte man im Verlauf der ganzen Bogenfurche fünf, bei Fötus 4 neun. Die Fiss. parieto-occ. und calc. standen bei Fötus 4 zur Bogenfurche ungefähr noch in demselben Verhältniss wie bei Fötus 3. Ausser der Parieto-occ. und calc. verschwinden übrigen diese radiären Furchen der medialen Hemisphärenwände dieser Entwicklungsperiode sammt und sonders wieder und theilen so das Geschick der schon früher erwähnten occipitalen Falten früherer stadien, obschon sie wie diese Totalfalten im His'schen sinne sind."

Ecker³ expresses himself on this question with considerable doubt and caution. "Moreover," he remarks, "it appears to me that one of the latter, viz., the *fissura parieto-occipitalis* is formed out of one of the temporary furrows, although I do not venture to assert this." This statement is rendered all the more ambiguous by the fact that in his description of the brain of a third-month foetus he asserts that the occipital lobe does not exist. Undoubtedly the fissure in dispute (the precursor of the parieto-occipital) is present at this stage. Further, he figures the parieto-occipital and the calcarine fissures in a brain at the fourth month, although he appears to infer that they arise more frequently in the course of the fifth month.

According to Mihalkovics,⁴ the calcarine fissure is the first to appear. It is formed at the end of the third month, and arises with the outgrowth of the occipital lobe almost simultaneously with the transitory furrows. The parieto-occipital sulcus is formed shortly after it at the commencement of the fourth month.

¹ *Entwicklungsgeschichte des Menschen und der höheren Thiere*, 1879.

² "Ueber die Entstehung der Grosshirnwindungen," *Virchow's Archiv*, 1887, p. 398.

³ "Zur Entwicklungsgeschichte der Furchen und Windungen der Grosshirnhemisphären im Fötus des Menschen," *Archiv für Anthrop.*, 1869.

⁴ *Entwicklungsgeschichte des Gehirns*, Leipzig, 1877.

Having now stated the views of those authors who have dealt with this question, I shall proceed to state the conclusions at which I have arrived regarding the parieto-occipital and calcarine fissures in the course of my study of the complete fissures.

At the same time, that the transitory fissures appear on the medial face of the hemisphere (towards the end of the second month, or it may be towards the beginning of the third month) two fissures which have a synchronous origin, and lie in series with these, occupy positions which give them a close resemblance to the parieto-occipital and calcarine fissures of the fully-developed brain. Between them is placed the cuneus. I have never seen these fissures absent, and in all good illustrations of the medial face of the hemisphere (v. Kölliker, Richter, &c.) they are represented. We have already referred to these infoldings as the precursors of the parieto-occipital and calcarine fissures.

One or other, or perhaps in some cases both, of these precursors may be retained and ultimately form the respective adult fissure or fissures. Most frequently, however, one disappears whilst the other is preserved. That which is obliterated is replaced later on (in the fifth month, or towards the beginning of the sixth month) by the permanent furrow, and this takes up the same ground as its precursor, although it does not show an unbroken continuity of existence with it. It is questionable if both precursors ever disappear again to be replaced by secondary successors.

It is difficult to say which of the precursory infoldings most frequently disappears. I am of opinion, however, that it is the parieto-occipital, and this view is quite in keeping with the phylogenetic evidence which we have on the question. In the Apes there cannot be a doubt but that the calcarine fissure is the most stable of the two. About the fifth month of intra-uterine life it is not uncommon to find hemispheres in which the parieto-occipital is totally absent, although the calcarine is present (fig. 7, B. and C.). Sometimes, however, at this stage, in addition to a well-marked calcarine fissure, a faint trace of the parieto-occipital may be visible. In two hemispheres from the same foetus, in my possession, the calcarine alone is present

on the left side, whilst on the right side there is also a weak indication of the parieto-occipital (fig. 9, A. and B.). It is hard to determine in this case whether the faintly-marked parieto-occipital is in process of obliteration, or in process of formation. On the ventricular face of the hemisphere wall a prominence corresponded with the weakly-marked parieto-occipital fissure, and this taken in conjunction with the fact that in the initial stages of the reappearance of the calcarine fissure, in cases where its precursor has been obliterated, I have failed to detect such a projection, makes me incline to the view that the parieto-occipital in this instance is really in process of obliteration.

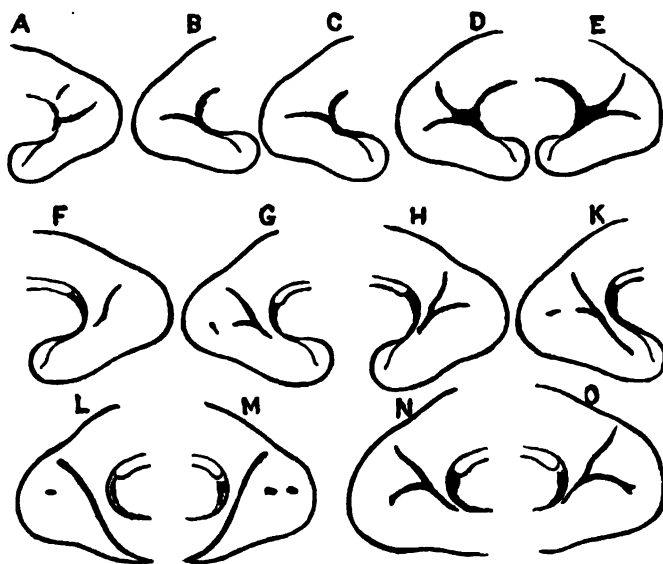


FIG. 7.—Different forms assumed by the parieto-occipital and calcarine fissures at different stages of their development.

His¹ has called attention to the fact that in certain foetal brains of the fifth month the calcarine fissure may exist alone on the one hemisphere, whilst on the other the parieto-occipital only is developed.

But from the beginning of the fifth month, and onwards, another condition is frequently met with. In this both fissures

¹ *Unsere Körperform*, Neunter Brief, p. 114.

are present (fig. 7, D. and E.). They converge towards a broad shallow gutter or furrow, by which they are led forward into the hippocampal fissure. The typical <-shaped condition is thus assumed, and this persists throughout the further development of the brain. In such a case it is probable that we have a retention of both precursory fissures. His figures a hemisphere which shows this disposition of the fissures, and he considers that the brain from which the drawing is taken had reached a stage of development corresponding to four and a half months. From the fact, however, that the corpus callosum is represented in the fully-developed condition, and that traces of the calloso-marginal sulcus are indicated, it is likely that the foetus from which the brain was taken was somewhat more advanced.

I have only seen one hemisphere in which the parieto-occipital fissure was present alone, without a trace of the calcarine¹ (fig. 7, F.). This belonged to a foetus which had reached a stage of development corresponding to the end of the fifth month. On the other hand, I have observed several in which the parieto-occipital was the predominant fissure, and in which the calcarine was so poorly developed that we could only conclude that it was in its initial stages of reappearance. It is somewhat curious that the hemispheres in which this condition was present were all at a somewhat advanced stage of development, viz., at the sixth month, or at least close upon it. In these cases the reappearing calcarine may assume several forms:—(1) It may appear as a short, weak branch, stretching backwards for a short distance from the lower part of the parieto-occipital (fig. 7, H.); (2) as a short branch in connection with the parieto-occipital, but also with an additional small detached piece lying nearer the occipital pole, and in the line of the future fissure (fig. 7, G. and K.); (3) as one or two detached and isolated pieces which lie in the line of the future fissure, and which are in no way connected with each other or the parieto-occipital fissure (L. and M.).

This last mode of development, viz., by isolated portions which ultimately run into each other, is frequently observed in con-

¹ Since writing the above two additional hemispheres of this kind have come into my possession.

nection with the cortical and permanent sulci. Thus the intra-parietal, the calloso-marginal, and the supero-frontal sulci frequently afford examples of this; and it is even not uncommon to see the same mode of development in the case of the fissure of Rolando.¹ When a section is made through the occipital lobe, in cases where the calcarine fissure is merely represented by these slight depressions, it is seen that they produce no corresponding elevation on the ventricular aspect of the hemisphere wall.

In both hemispheres of a fœtus which had arrived at the end of the fifth month, or the beginning of the sixth month, the parieto-occipital fissure presented a very remarkable development. Instead of ending a short distance below the hinder end of the corpus callosum, it was prolonged downwards and forwards as a deep fissure, which reached the lower border of the temporo-sphenoidal lobe (fig. 7, L. and M.). The calcarine fissure was present as two short isolated portions or depressions, and the part of the parieto-occipital fissure below the line of these was at least three times as long as the part above. The long lower part must be regarded as transitory. In the further development of the brain it would in all probability have become obliterated. In this case the appearance presented by each hemisphere suggested as the cause of this long fissure the bending, in an inward direction, of the entire hinder part. The fissure formed the angle of bending.

The typical <-shaped condition of the combined parieto-occipital and calcarine fissures appears to be invariably assumed between the sixth and seventh months of fœtal life (fig. 7, N. and O.), although, as we have seen, it is frequently assumed at the fifth month. Even at the seventh month, however, it is not at all uncommon to find a marked difference in the degree of development of the two fissures, and in the manner in which they influence the ventricular aspect of the cerebral wall in different brains. In some cases it is the calcarine which is deepest and continuous with the stem of the <. A distinct hippocampal elevation on

¹ The fact that the fissure of Rolando may first appear in two pieces—one near the free border and the other near the Sylvian fossa,—which ultimately run into each other, shows at once how erroneous the view advanced by Krause as to its origin is. To this we shall refer in a subsequent chapter of this memoir.

the ventricular aspect of the hemisphere wall marks its course. The parieto-occipital fissure in such cases is a shallow furrow, and produces no ventricular eminence. In other instances exactly the reverse condition may be noticed. The parieto-occipital fissure is present as a deep infolding, continuous with the stem of the \angle , whilst the calcarine fissure is shallow. Consequently, on opening the posterior horn of the ventricular cavity by the removal of the outer wall, very different appearances may be seen in different brains:—(1) Two elevations, corresponding to the two fissures, may be seen on the ventricular aspect of the inner wall. I do not possess a specimen which shows this condition, but, where both fissures persist from the precursory stage, it is reasonable to assume that the corresponding ventricular elevations will persist also. (2) In other instances, one ventricular elevation alone is present. This may correspond with the calcarine, in which case it proceeds in a more or less horizontal direction from behind forwards, or it may correspond with the parieto-occipital, in which case it descends from above, and takes a curved direction from above downwards and forwards. The deep fissure with the infolding on the ventricular aspect of the hemisphere wall may be regarded as the one which has persisted from the precursory stage. The other is secondary, having been, in the first instance wiped out prior to its permanent reappearance.

*Greatest Depth in Millimetres of the Parieto-occipital
and Calcarine Fissures.*

No. of Observation.	Age of Fœtus.	Parieto-occipital.		Hinder part of Calcarine.	
		Right Hemisphere.	Left Hemisphere.	Right Hemisphere.	Left Hemisphere.
1	Commencement of 7th month	2	4	3	1
26	28 weeks	2	1	2	—
11	7th month	4	4	2	2
38	29 weeks	3	3	5	4
25	29 weeks	5	4	5	5
15	30 weeks	6	7	3	2

N.B.—Large figures are used where there is a striking difference in the depth of the calcarine and parieto-occipital fissures on the same hemisphere.

A study of an excellent paper, which has recently been published by Dr J. Mingazzini¹ of Rome, makes it very evident that about the beginning of the seventh month it is extremely common to find one fissure deep and the other shallow. I may be allowed to extract from the useful tables which this author gives the items contained in the Table on preceding page:—

Pansch² raises a question as to the position which the stem of the < occupies with reference to the two fissures. He says:—

“Zu welchen dieser beiden der Stamm des Y gehört, oder ob dieser wechselt, oder ob er vielleicht zuweilen isolirt entsteht, wage ich noch nicht endgültig zu entscheiden.”

This is an important question, because in the adult human brain it is the back part of the stem which is chiefly related to the calcar avis. The parieto-occipital fissure above the stem has no relation whatever to the ventricular cavity, because above the level of its junction with the calcarine fissure the cerebral hemisphere has become solid through the increase of the white substance. If the stem, therefore, does not belong to the parieto-occipital, this fissure forms no permanent bulging into the ventricular cavity.

Upon phylogenetic grounds, we might infer that the stem belongs solely to the calcarine fissure. In the Chimpanzee the parieto-occipital does not run into it, but is separated from it by a thick superficial convolution. In many human brains this convolution is represented by a deep bridging gyrus, which acts as a feeble barrier to the free communication between the two fissures. In the Orang the condition may be exactly the same as in the Chimpanzee, or resemble that present in Man. In an Orang's brain in my possession the right hemisphere shows a free communication between the parieto-occipital and calcarine fissures, whilst on the opposite side the two fissures are completely separated by a superficial convolution.

But on studying the ontogenetic evolution of the two fissures, it becomes apparent that in the human brain the stem of the

¹ “Ueber die Entwicklung der Furchen und Windungen des Menschlichen Gehirns,” aus *Untersuchungen zur Naturlehre des Menschen und der Thiere*, herausgegeben von Jac. Moleschott, xiii. Band, 6 Heft.

² “Ueber die typische anordnung der Furchen und Windungen,” &c., *Archiv für Anthrop.*, 1869, p. 232.

> may have a different connection in different specimens. In cases where both fissures persist from the precursory stage the stem is common to both. It is the lineal descendant of the broad shallow gutter, which we have noticed in some brains at the fifth month, leading forwards to the hippocampal fissure. It is formed by a depression of that portion of the primitive gyrus fornicatus, which lies between the two anterior extremities of the precursory fissures. In other cases, it is formed by that fissure, which persists after the obliteration of its fellow. Sometimes, therefore, the stem belongs to the parieto-occipital, sometimes to the calcarine, whilst there are still other instances in which it is common to both.

This affords an explanation as to the very different degrees of development we continually observe in the calcar avis in the adult human brain. When the calcar avis is small and feebly marked, it corresponds only with the back part of the stem of the <, and in this case it is probable that the parieto-occipital fissure is solely responsible for its production. When, on the other hand, it is a strongly marked prominence it will be seen that it is related not only to the stem of the <, but also to a portion of its calcarine branch.

In the Chimpanzee the calcar avis is very strongly marked, and produced from end to end by the calcarine fissure. Close to the place where the posterior horn joins the body of the ventricle another elevation, placed above the calcar avis, is sometimes to be remarked, and this seems to correspond with the lower end of the parieto-occipital fissure. It is right to add, however, that although I have made sections of two hemispheres from different brains, with the view of clearing up this latter point, I cannot say that I am absolutely satisfied upon it.

External Calcarine and External Perpendicular Fissures.
—In his elaborate memoir upon the convolutions of the human brain and their development in the foetus, Bischoff¹ describes and figures a transitory fissure on the outer surface of the cerebral hemisphere under the name of "fissura perpendicularis externa." He states that it appears in the seventh month in the form of a furrow, which runs downwards in a

¹ *Abhandl. der k. bayer Akad. der Wiss.*, 11 Cl. x. Bd. 11 Abth.

vertical direction over the hinder end of the hemisphere, and that it is obliterated in the eighth month. It belongs to that class of formations, therefore, he remarks, which only in certain forms attain their complete development, whilst in others they are arrested or completely disappear.

That such a fissure occasionally exists there cannot be a doubt. Further, it is a complete fissure, and produced by a distinct infolding of the hemisphere wall. But Ecker has very rightly pointed that it is not between the seventh and eighth months of foetal life that it is to be seen, but much earlier. It appears, according to Ecker, in the fifth month, but disappears before the sixth month is reached.

On very few occasions have I ever seen the *fissura perpendicularis externa* as it is figured by Bischoff. The best example which has come under my notice is in a brain apparently a little over the fifth month, which is preserved in the museum of the Oxford University, and of which Professor Horsley has very kindly given me a photograph. A tracing from this is repro-



FIG. 8.

duced in the text (fig. 8, E.P.). The fissure in question is situated on the outer surface of the occipital lobe very much on a line with the parieto-occipital fissure on the medial face of the hemisphere, but it is placed a little further back. It therefore occupies the position of the "Affenspalte" in the Ape's brain, and I have little doubt that Bischoff is right in supposing it to be the representative of the latter.¹ In the January number of this *Journal* I have endeavoured to show that the sulcus transversus of Ecker cannot (in its entirety at least) be regarded as equivalent to the "Affenspalte," and this being

¹ In a former paper upon the "Intraparietal Sulcus" (*Journ. Anat. and Phys.*, Jan. 1890), I expressed a different opinion, but I am now satisfied that in this I was wrong.

assumed, the fact of the early disappearance of Bischoff's fissura perpendicularis externa cannot be quoted as evidence against its being the transitory representative in the human foetus of the "Affenspalte." Lately I have obtained the brain of a newly-born male child (fig. 9), which shows a condition bearing very closely upon this question. The sulcus transversus of Ecker (S.T.) is present, but behind it there is another and larger transverse sulcus, which communicates below with the former, and which I am strongly convinced represents a persistent condition of the fissura perpendicularis externa, or in other words, of the "Affenspalte."

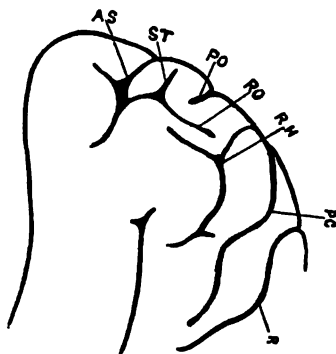


FIG. 9.—Right hemisphere of new-born child. R, fissure of Rolando; P.C, post-central sulcus; R.H, ramus horizontalis of the intraparietal fissure; R.O, ramus occipitalis; S.T, sulcus transversus occipitalis of Ecker; A.S, Affenspalte.

This is not the place to discuss Wernicke's¹ views regarding the "Affenspalte" (his "vordere Occipitalfurche"), but I may be allowed to say that the fissure in the human brain, which he considers to be its representative, lies in a position which puts it out of the question altogether. As the views of this author, however, have received some acceptance, it will be necessary to come back upon this point on a future occasion.

For a time I was inclined to regard the fissure which I have named the external calcarine as the same as the fissura perpendicularis externa, but its position and direction are such

¹ "Das Urwindungssystem des Menschlichen Gehirns," *Archiv für Psychiatrie*, Band vi. Heft 1, 1875.

that I now consider it necessary to look upon it as a distinct fissure. It is placed very obliquely along the lower border of the occipital part of the cerebrum (fig. 10, No. 1), and corresponds on the outer surface of the hemisphere with the calcarine fissure on the mesial face. When transverse sections are made through the occipital part of the cerebral hemisphere, the external calcarine fissure is seen to be a deep infolding of the hemisphere wall, and the bulging which it forms into the ventricular cavity lies exactly opposite, and may be actually in contact with the calcar avis (fig. 10, Nos. 2, 3, and 4).

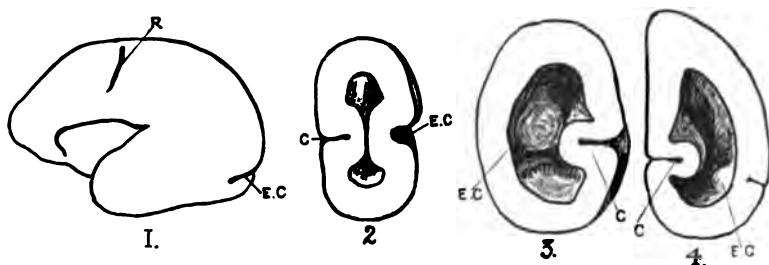


FIG. 10.—No. 1, left hemisphere of fifth month fœtus : R, fissure of Rolando ; E.C, external calcarine. No. 2, coronal section through the occipital region of the same hemisphere ; C, calcarine fissure ; E.C, external calcarine. Nos. 3 and 4, coronal sections through the two hemispheres of a fifth month fœtus. Lettering the same as in No. 2.

The external calcarine fissure appears very early. It can be distinguished in a large number of cases amongst the primitive transitory furrows (figs. 2, 4, and 5, E.C.), and at this period, as we have already noticed, it is frequently continuous around the occipital pole of the hemisphere with the precursor of the true calcarine fissure. This connection, where it exists, is always obliterated about the fourth month. In the human brain the external fissure is transitory. It is effaced about the sixth month. It is a much more constant fissure than the external perpendicular of Bischoff, although in certain cases it also fails completely.

Although evanescent in the brain of Man, there is strong reason to believe that it has a permanent representative in the brain of the Ape. On the outer surface of the occipital lobe of most Apes a deep fissure runs horizontally forwards and comes to an end a short distance behind the free anterior lip of the

operculum. This fissure is placed on the outer face of the hemisphere in an exactly corresponding position to the calcarine fissure on the mesial face, but it is shorter than the calcarine fissure, and its anterior end, in most of the numerous specimens I have examined, just falls short of the posterior horn of the lateral ventricle. In two species, however, both of which belonged to the genus *Cercopithecus*, the fissure in question reached as far forwards as the posterior part of the ventricular cavity, and formed a slight bulging on the outer ventricular wall opposite to the calcar avis on the inner wall (fig. 11). The second occipital

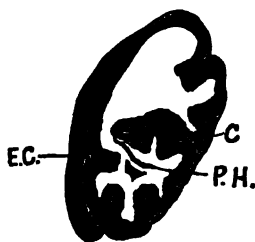


FIG. 11.—Coronal section through the occipital region of the hemisphere of a *Cercopithecine* Ape. E.C, external calcarine fissure; C, calcarine fissure; P.H., posterior horn of lateral ventricle.

sulcus in the human brain apparently corresponds with this fissure in the cerebrum of the Ape—at least it corresponds to it in position, but not exactly in history, although it is quite reasonable to suppose that the external calcarine is the precursor of the second occipital fissure in Man, in the same way that the true calcarine fissure itself is sometimes preceded by a temporary precursor.

Whilst in the description of these two transitory fissures on the outer aspect of the occipital lobe of the foetal brain I have inclined to the view that they are to be regarded as distinct fissural integers, I am not blinded to the fact that it is possible that we may really be dealing with one and the same fissure, which alters slightly in position according to the kind of growth-restraint which is put upon the brain. Until they are both seen together on the same hemisphere, this question cannot be definitely settled; but, at the same time, in support of the view that they are distinct and separate, I might call attention to the following points:—(1) The fissures in the Ape, which I

believe they represent (viz., the *bottom* of the "Affenspalte" and the external calcarine), are in very close proximity to each other when we completely remove the operculum. (2) There is grave reason to suppose that the "Affenspalte," except in exceptional cases, is not permanently represented in the human brain. This would account for the rare occasions in which the external perpendicular appears even in a transitory state in the human foetus. (3) If we regard the external calcarine as the precursor of the second occipital furrow, we have an explanation of the greater frequency of its appearance in a transitory form in the foetal brain.

Relation of the Appearance and Obliteration of the Transitory Fissures to the Growth of the Cerebral Hemispheres and the Mapping-out of an Occipital Lobe.—The transitory infoldings of the early hemisphere wall play an important part in the general growth of the cerebrum, and in the appearance of an occipital lobe. When we read the accounts which are given of the formation of the occipital lobe, an impression is conveyed to the mind that this part of the cerebrum is a local outgrowth or bud which grows backwards from the hinder and upper part of the hemisphere about the beginning of the fourth month; in other words, that it is a secondary formation.

Such is the view which is advanced by Schwalbe, and it may be regarded as giving expression to the opinion which is held by many anatomists on this question. He says:—"We have to separate on developmental grounds the annular lobes (ringförmiger Lappen) from the occipital lobes, which have a *secondary* origin, and which are only present in characteristic development in Man and the Apes."¹

According to Ecker,² the occipital lobe does not exist in the third month; they only appear in the fourth month. He applies the term "Aus sackung," or pouching out, to the process of formation. Pansch³ speaks of the occipital lobe as a hinder "Auswuchs," which, taken along with the context, clearly shows that he regarded the production of the occipital lobe as due to local growth restricted to the hinder end of the hemisphere. Mihalkovics⁴ calls the occipital lobe a "Nebenfortsatz," or accessory projection, and frequently refers to the early condition of the hemisphere in which, as he remarks, it only

¹ *Lehrbuch der Neurologie*, Erlangen, 1881, p. 534.

² *Archiv f. Anthropologie*, Dritter Band, 1869, p. 208.

³ *Ibid.*, p. 232.

⁴ *Entwicklungsgeschichte des Gehirns*, 1887, p. 111.

consists of a frontal, temporal, and parietal lobe. Krause¹ applies the term "secundärer Auswuchs" and "secundärer Bildung" to it; and Richter,² who, as we have seen, admits the very early appearance of the calcarine and parieto-occipital fissures, nevertheless speaks as if he regarded the budding-out of the occipital lobe to be a process analogous to the outgrowth of the optic vesicle.

But, whilst the majority of anatomists would appear to take this view of the formation of the occipital lobe, there are two who have expressed themselves in very different terms. I refer to v. Kölliker and to His. The opinion which v. Kölliker³ holds regarding the origin of the calcarine and parieto-occipital fissures necessarily entails, as a part of it, the existence from a very early period of a portion of the brain which corresponds to an occipital lobe. His⁴ gives an admirable account of the mode in which the occipital lobe is moulded into shape. He explains that it owes its existence to the strong development of the "Brückenkrümmung," which, in the primate brain, carries the cerebellum and pons downwards and forwards. His whole description shows that he regards the appearance of the occipital lobe as being due to a general, and not to a local growth.

There are many points which indicate in the clearest manner that the occipital lobe is not a local secondary outgrowth which has sprouted out from the hinder end of the cerebral hemisphere in a bud-like fashion. From the end of the second to about the beginning of the fourth month the young embryonic human cerebrum presents the characteristic bean-shaped outline which has led German authors to apply to it the term "ringförmiger Lappen." At this stage the primate cerebral hemisphere resembles in outline the adult condition of the hemisphere in most quadrupeds. A further similarity may be noted in the fact that the Sylvian fissure in the quadrupedal brain stands upright and nearly vertical, and thus corresponds with the vertical direction of the Sylvian fossa in the foetal primate cerebrum. But as the occipital lobe in the latter takes form, the Sylvian fossa becomes more and more oblique, which clearly shows that the growth is not restricted to the hinder end of the hemisphere, but affects it from one end to the other—in other words, that it is interstitial and general.

The shape of the occipital part of the cerebrum depends upon the restricted space it is called upon to occupy above the cere-

¹ *Handbuch der menschlichen Anatomie*, Zweiter Band, 1879, pp. 728, 729.

² *Archiv f. Path. Anat.*, Virchow, 1887, p. 421.

³ *Entwicklungsgeschichte des Menschen und der höheren Thiere*, 1879.

⁴ *Unsere Körperform*, 1875, Neunter Brief, p. 115.

bellum. As it is pushed backwards by the general cerebral growth it is moulded into shape by its surroundings, and its very existence depends, as His has pointed out, upon the strong "Brückenkrümmung" of the embryonic primate brain. This backward thrusting also of the posterior part of the hemisphere is chiefly instrumental in preserving the precursory calcarine and parieto-occipital fissures, or causing their reappearance should they have previously become obliterated. The infoldings on the outer aspect of the occipital lobe (external calcarine and external perpendicular) owe their origin to the same influence. But the outer wall of the hemisphere is less hemmed in than the mesial, and consequently there is greater reason for the external infoldings being temporary and less constant than the internal or mesial. Further, those cases which I have mentioned, in which the parieto-occipital fissure traverses the entire depth of the mesial and tentorial aspects of the cerebrum, are explained.

The transitory fissures on the outer surface of the cerebral hemisphere make their appearance, as we have noted, about the beginning of the third month, and undergo obliteration towards the end of the fourth month, viz., at the time when the occipital lobe becomes clearly mapped out as a distinct portion of the cerebrum. This is a circumstance which is deeply suggestive and significant. The majority of observers who have studied the transitory fissures are agreed in ascribing their formation to a more rapid growth of the hemisphere wall than of the skull-capsule within which it is enclosed. The necessary result of such a growth-restraint is, that the thin wall of the hemisphere becomes folded along lines which run at right angles to the axis of growth-energy. But no one has attempted to explain why, at this period, the growth-rate of the skull-capsule and of the contained cerebrum should be at variance with each other. We may, I think, take for granted that the cerebral infoldings occur only in the embryonic brain of primates. Schmidt failed to observe them in Sheep, Oxen, or Pigs, although he thought he saw weak traces of them in the embryo of the Cat.¹ This latter statement I cannot verify. Although

¹ "Beiträge zur Entwicklungsgeschichte des Gehirns," *Zeitsch. f. Wiss. Zool.*, Bd. xi. 1862.

I have looked for the transitory fissures in Cat and Dog embryos of different stages, I have never seen any infolding of the cerebral wall that could be compared with those we have described in connection with the human brain. It is clearly a question which requires further investigation.

The temporary fissures, therefore, are in all probability peculiar to the primates; they occur at a stage of growth prior to the appearance of a well-marked occipital lobe; the great majority of them are effaced when this portion of the cerebrum is moulded into shape; and, lastly, their formation appears to be due to a want of harmony between the growth-rate of the cerebrum and of the skull-capsule. How can these facts be explained?

We may assume that, although cranial and brain-growth, as a rule, go on smoothly and evenly and in perfect harmony with each other, all steps towards an advance of development must be initiated within the brain, and that, for a time at least, the enclosing skull-capsule will resist these. This being granted, we can readily understand that the tendency towards the cerebral growth which gives rise to a well-mapped out occipital lobe is more firmly impressed upon the brain than upon the skull. When the primate head reaches in its development the quadrupedal stage, the cerebrum goes on, without any intermission in its growth, towards the higher development and the formation of a distinct occipital lobe. The cranium, however, pauses in its growth. But this quadrupedal pause marks only a stage in its evolution; it is merely temporary, although it is of sufficient duration to produce the infoldings of the cerebral wall.

But against this view it may be argued that the temporary fissures appear before the third month on the mesial face of the hemisphere. It must be remembered, however, the conditions of growth on the mesial face are different from those on the outer surface of the hemisphere. In the first place, the inner wall is distinctly thinner than the outer wall; and, as His has pointed out,

"through the hemispheres being opposed to each other in the mesial plane, and the space thus restricted, they exercise an influence on each other. Instead of being able by bulging to push themselves out, they are required to adapt themselves to the even and plain bounding surface."¹

¹ *Unsere Körperform*, Neunter Brief, p. 112.

I have already referred (page 326) to the preservation of the temporary fissures on the outer surface of a brain described by Dr Hans Virchow. I have reproduced a tracing from the photograph which the author gives of this brain, and it is a matter of extreme interest to observe that the cerebrum presents an outline similar to that of a brain between the third and fourth months of intra-uterine life. The growth which would have led to the mapping out of a distinct occipital lobe has been arrested, and, consequently, the temporary fissures have been retained. The general similarity in outline to that of a quadrupedal brain is very marked.

Further evidence in support of the view which I have advanced might be adduced from the fact that variations in the capacity of the hinder part of the cranium are much greater than those in the fore part.¹

Considering, then, that the occipital lobe in primates owes its origin to a general growth of the cerebral hemisphere, and not to the sprouting out of a local bud from its hinder end, it would be wrong to deny the presence of a corresponding portion of the cerebrum in the lower mammals. From this point of view, Benedikt² has some ground for his assertion that in the mammalia generally there is an occipital lobe. Upon his further statement that the calcarine fissure is also developed in brains below the primates we are not in a position at present to offer an opinion.

With the expansion of the cranial cavity the temporary fissures become obliterated by the partial opening out of the infoldings. The cerebrum at the same time increases in length and the occipital lobe comes clearly into view. But the increase in length is not so great as that which would be produced by the complete opening out of all the transitory infoldings of the cerebral wall. This can readily be proved by measuring the depth of the fissures and calculating the increase in length which the cerebrum has undergone between the time when these fissures were present and the period when it is entirely smooth. The question, therefore, comes to be—What becomes

¹ Virchow's *Gesammelte Abhandlungen zur wissenschaftlichen Medicin*, 1856.

² *Der Hinterhauptslappen der Säugelhäute*, von Dr Moritz Benedikt (Wien). Sep. Abdr. a. d., *Centralbl. f. d. Med. Wissensch.*, 1877, No. 10.

of the deeper parts of the folds? To this, I suspect, we cannot offer a satisfactory answer. We have seen that Meckel, the original observer of these transitory fissures, was of opinion that their obliteration was due to the growing together of their opposed surfaces. Certain it is that the deepest part of the bottom of the infolding cannot reach the surface of the brain in every case unless it does so by a partial absorption of the walls of the fold. This, combined with the partial opening out of the fissures, may serve to account for their disappearance. Further research, however, is required in connection with this part of the inquiry, and this can only be conducted by one who has a large amount of particularly well-preserved material at his disposal.

Richter has advanced the theory that the choroid plexuses, as they expand in size, may have some influence in bringing about the unfolding of the temporary fissures, and in smoothing out the surface of the cerebral hemisphere.

In the course of my examination of the beautiful series of specimens in the museum of the University College, London, I met with a very remarkable deformity in the posterior part of the right cerebrum of a foetus between the third and fourth

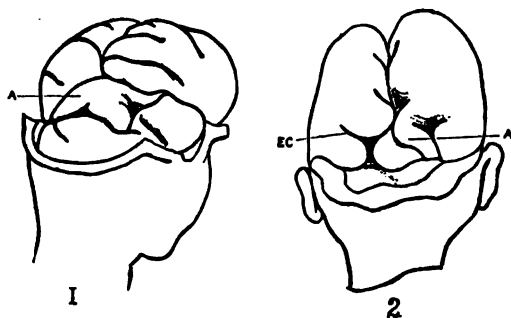


FIG. 12.

month. A hollow outgrowth projected backwards over the mesencephalon, upon the upper surface of which it was closely adapted. It was spread out, so as to cross the mesial plane, and its posterior border showed an angular deficiency which gave it a forked appearance (fig. 12, No. 1). The under wall of this outgrowth or lappet was formed of an epithelial layer only.

Its precise attachment to the cerebrum could not be made out without destroying the specimen, but it appeared to be attached by a stalk to the under and back part of the cerebrum. The posterior part of the temporo-sphenoidal lobe, which was completely separated from the remainder of the cerebrum by a deep temporary fissure, overlapped this stalk and hid its connections.

It is difficult to imagine what the further history of such an embryo would have been had it survived. The deformity cannot be very rare, as Richter has figured a specimen which shows a very similar condition (fig. 12, No. 2).

ON A FERMENTATION CAUSING THE SEPARATION
OF CYSTIN. (PRELIMINARY COMMUNICATION.) By
SHERIDAN DELÉPINE, M.B., B.Sc.

DURING the months of March and April 1889, I analysed for Dr Lauder Brunton, and under his direction, a number of specimens of urine containing cystin. The estimation of the amount of this substance present in the samples examined was carried out by Löbisch's process, and revealed certain variations which were of interest as connecting the elimination of cystin with the processes of digestion. In carrying out this work, I was struck with the fact that the amount of cystin precipitated from the same specimen was greater under certain circumstances than under others. Thus, (1) when specimens were *strongly acidified with acetic acid*, as recommended by Löbisch, the precipitation took place more slowly than if the specimens were allowed to undergo a *spontaneous acid fermentation* (which never caused the reaction to become very strongly acid). (2) When the fluids were *carefully filtered*, the precipitation of cystin was delayed, often for several days. (3) When a specimen in which cystin had begun to separate was *carefully filtered*, the precipitation was interrupted for several days. (4) When portions of a urine which was proved by collateral experiments to yield cystin were *kept at a temperature of 60° C.*, no cystin could be separated afterwards by the usual processes. (5) *Evaporation* did not seem to increase materially the amount of cystin obtainable from a given specimen. (6) The largest amounts of cystin could be obtained by allowing the *specimens to stand at the ordinary temperature for several days*, provided the precipitate was separated whilst the urine was still acid. (7) A similar amount of cystin could be obtained more rapidly by keeping the fluid at a *temperature higher than the normal, but less than 40° C.*, for twenty-four to thirty-six hours. (8) When a drop of urine from which cystin was being deposited was added to a portion of the same urine carefully filtered, a deposit of cystin occurred in twenty-four hours, while another

portion of the filtrate protected from organisms deposited no cystin for ninety-six hours. From all these facts I venture to conclude—

(1) That the *simple* addition of an acid in which cystin is not soluble is not sufficient to separate cystin from the urine, and, therefore, that the *theory generally held as to the state of combination of cystin in the urine is probably inaccurate.*

(2) That a compound exists in *certain* urines which under the *influence of a fermentation* yields cystin.

(3) That the fermentation is due to the *growth of an organism*, which can apparently be separated from the urine by ordinary filtration, and must therefore be a *large organism*, possibly (*but not necessarily a torula*).

(4) That the cases recorded in which cystin has been found deposited in the kidneys and liver indicate that the *separation may begin in the system* (whether owing to a fermentation, or to an oxidation process brought in some other way, cannot be decided at present).

APPENDIX.

In order to facilitate the understanding of the above facts, which may at first sight seem to be not quite conclusive, the following explanations may be found useful. (The numbers correspond to those used in the text.)

(1) *a.* Acetic acid is added with the view to displace cystin from a compound in which it is supposed to be fully formed (other acids are not used, because, with the exception of tartaric acid, cystin is soluble in them). If it were owing to the acid properties of acetic acid that cystin is precipitated, acetic acid should cause precipitation much more readily than the feeble acidity due to the ordinary acid fermentation of urine. *The reverse, however, takes place.*

β. Micro-organisms generally grow better in feebly alkaline or feebly acid solution than in strongly acid fluids, therefore, if the precipitation of cystin is due to a fermentation, strong acidification should delay it, *and that is what occurs.*

(2) The delay in precipitation caused by filtration, shows that before cystin is precipitated there is something in the fluid which can be separated by filtration, and in the absence of which cystin is not precipitated readily. The fact that precipitation is only delayed, shows that the body after being separated can form again in the fluid (under ordinary circumstances).

(3) That filtration stops the process of precipitation, even after it has begun, shows that the precipitation is not due to a simple chemical change taking place in the fluid either under the influence of an

enzyme or some other soluble compound; but that a gradual change takes place under the influence of a particulate body large enough to be separated by filtration through Swedish filter-paper.

(4) A temperature of 60° C. is much below that at which cystin is decomposed; it is, however, sufficient, when continuous, to stop the growth of micro-organisms.

(5) The fact that evaporation does not increase the amount of cystin obtainable from a given quantity of fluid, shows that during the fermentation process concentration of fluid has nothing to do with the separation of the crystals.

(7) A temperature of less than 40° C. does not cause the death, and favours the growth of many organisms; the accounts for the difference then is in the results obtained when the fluid is kept at temperatures above or below 40° C. See above (4).

(8) Inoculation is simply a confirmatory test of the conclusions which had been arrived at from the previous observations.

It is therefore evident—

(1st) That conditions which favour the growth of micro-organisms in a urine capable of yielding cystin, accelerate and increase the amount of cystin obtainable from that fluid.

(2nd) That conditions which hinder the growth or cause the removal or death of micro-organisms, retard or prevent the precipitation of cystin.

(3rd) That the direct addition of micro-organisms to the fluid caused a more rapid precipitation than simple acidification.

(4th) That some of the methods used in separating organisms from the fluid, showed that the most important of these organisms must be a large one, such as a torula.

Hence the general conclusions arrived at.

THE ORBITO-MAXILLARY FRONTAL SUTURE IN
MAN AND THE APES, WITH NOTES ON THE
VARIETIES OF THE HUMAN LACHRYMAL BONE.
By ARTHUR THOMSON, M.A. Oxon., M.B. Edin., *Lecturer
on Human Anatomy in the University of Oxford.*

IN his monograph on the Human Crania, published in the "Challenger" Reports,¹ Professor Sir W. Turner has directed attention to an unusual arrangement of the sutures on the inner wall of the human orbit in two crania of the Bush race. With the object of ascertaining whether a similar condition was to be found in any of the crania in the Oxford collection, I made an examination of all the specimens—1037 in number. In a large majority of cases the orbits were mutilated, but some notes which I took may be useful as an addition to the literature of the subject.

Professor Alexander Macalister has already discussed the anatomy of the human lachrymal bone at such length, and in such detail,² that the present communication may be regarded as a supplement to his elaborate paper. The reader is therefore referred to his memoir for information regarding the literature of the subject.

I. Professor Macalister treats, in the first instance, of cases of deficiency of the lachrymal bone. Of such I found two examples—one in an aboriginal Australian from New South Wales, the other in a native of the Andaman Islands. In neither case was there any evidence of synostosis, nor were any lacunæ present such as Macalister describes.

II. *Rudimental State of the Bone.*—In three specimens the lachrymal bone was represented only by its lower segment. This condition occurred in a North American Indian and in two Australian skulls. In each instance the ethmoid arti-

¹ "Challenger" Reports, *Zoology*, vol. x. part xxix. plate i. fig. 4.

² *Proc. Roy. Soc.*, vol. xxxvii., 1884, p. 229, "Notes on the Varieties and Morphology of the Human Lachrymal Bone and its Accessory Ossicles," A. Macalister, F.R.S.

culated anteriorly with the nasal process of the superior maxilla above the rudimentary lachrymal.

In a Gallo-Roman skull the lachrymal bone was well developed, but distinctly divided into upper and lower segments by an open suture. A similar condition was noticed in a specimen from the Central Carolines. Other conditions, similar to those already recorded¹ by Macalister, were noticed, viz., those in which there was a narrowing of the bone corresponding more or less closely to the position of the crest, and also those in which the bone presented a fenestrated appearance.

III. *Variations in Outline*.—I have not attempted any classification of the innumerable forms observed.

IV. *Varieties of Crista Lachrymalis and of Hamulus*. Four types.

- A. Simple lamellar forms with obsolete crest.
- B. Simple carinate forms.
- C. Carino-acuminate forms.
- D. Carino-hamate form.

The notes I took at the time of my observations were not such as to enable me to distinguish between Groups A, B, and C, which I am only able to classify together as a group in which the crista does not reach forward inferiorly to articulate with the root of the nasal process of the superior maxilla on its orbital border. Such an arrangement exists in about 61 per cent. of the specimens examined.

The remaining specimens—39 per cent. in the Oxford series—may be considered as corresponding to Group D of Professor Macalister's classification, viz., those bones which articulate with the orbital margin of the nasal process of the superior maxilla by means of a processus hamatus. The percentage of Professor Macalister's specimens and those in the Oxford collection are identical. In six specimens—one Hindoo, three North American Indians, and two Australians—the hamulus was pierced by a foramen, presumably for the passage of a blood-vessel.

In regard to Groups VI. and VII. of Professor Macalister's classification (VI., the vascular relations of the lachrymal bone, and VII., the disposition of the periosteum on its outer surface),

¹ *Loc. cit.*

I have nothing to add, my observations having been entirely confined to macerated specimens.

VIII. Six separate ossicles occur around the margin of the lachrymal bone:—

1. Ossiculum ethmo-lachrymale superius.
2. Ossiculum ethmo-lachrymale inferius.
3. Ossiculum canalis naso-lachrymalis.
4. Ossiculum hamuli.
5. Ossiculum infra-orbitale.
6. Ossiculum maxillo-frontale.

1. Of the first variety only two specimens were noted—one in a skull taken from a Roman camp and one in the case of a Hindoo (fig. 1, A). Of doubtful instances two cases are recorded; for, as Macalister has pointed out, when of large size, the ossicle is probably ethmoidal in origin.

2. The only specimen displaying a distinct ossiculum ethmo-lachrymale inferius is that of a Talauerese (fig. 1, B). As above, there are instances in which an ossicle occupying this position is more probably a detached portion of the os planum (fig. 2, A).

3. Ossiculum canalis naso-lachrymalis. I find in my notes only ten instances recorded, but in each case it is necessary to explain that the ossicle was quite distinct, and not ankylosed with any of the surrounding bones. This fact may account for the striking difference between the present observations and the averages of Rousseau, Krause, and Macalister. The latter authority states that there are traces of its existence in 55 per cent. of the crania examined.

4. The ossiculum hamuli, as described by Macalister, consists of a separate ossification in the membranous hamulus at its attachment to the anterior border of the lachrymal groove. The percentage of specimens in the Oxford Collection, a little over $1\frac{1}{2}$ per cent., is in accord with Professor Macalister's observations.

5. In regard to the ossiculum infra-orbitale, and 6, the ossiculum maxillo-frontale, my attention was not directed to these anomalies at the time I examined the collection.

As previously stated, the intention of the present inquiry was rather to obtain information with regard to the presence of a maxillo-frontal articulation separating the lachrymal from the eth-

moid, as recorded by Professor Sir W. Turner, who has enumerated two instances of its occurrence in Bush skulls. On looking over the plates appended to Professor Macalister's paper, I find one instance figured—viz., pl. iii. fig. 20. Referring to my own notes, I find two cases in which the orbital plate of the superior maxilla and frontal touch each other by long and pointed processes, which are wedged in between the ethmoid and lachrymal above and below (fig. 1, c). One can best explain the occurrence of this anomaly by supposing that in each instance we have had ossicula ethmo-lachrymalia superiora and inferiora,¹ and that in the subsequent development of the orbital wall these ossicles have become fused with the frontal and superior maxillary bones respectively. The crania in which the above condition was observed are a Patagonian and a native of the Solomon Islands.

Of cases resembling that figured by Turner, I find three instances—viz., a Chatham Islander, a Maori, and an Andamanese (fig. 2, c); in the two former the condition is somewhat obscure, owing to the degree to which surrounding synostosis has taken place, though the bulk of the evidence is in favour of regarding them as distinct instances of this anomalous arrangement. In regard to the Andamanese, the sutures are still open and well defined. A striking point to be noted in this case is, that it is co-existent with an entire absence of the lachrymal bone. The specimen figured by Macalister (pl. iii. fig. 20) is precisely similar; and though he does not direct attention to the occurrence of the maxillo-frontal suture in the text explanatory of the plate, yet the arrangement is evident in the figure itself. In the figure given in the "Challenger" Reports, whilst the suture is plainly indicated, the outline of the lachrymal bone, if it exist, is obscured by the shading, so that I am unable to state precisely what the condition is.

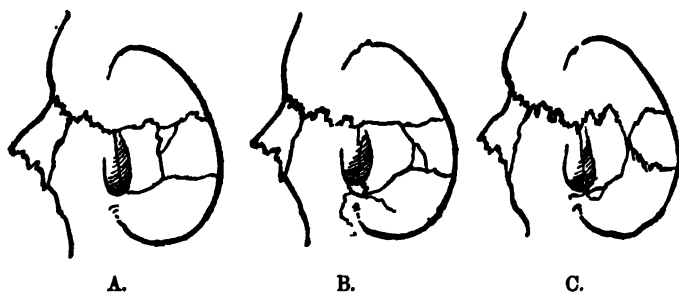
It must be pointed out in this connection, that when the lachrymal bone is absent its place is taken by a backward

¹ Professor Macalister figures such a condition in pl. ii. fig. 11, where both upper and lower ossicles are present; in that instance, however, the ossicles are small, and the lachrymal and ethmoid articulate between them. Still the specimen is interesting as demonstrating the feasibility of such a condition being antecedent to the pointed variety of articulation above described.

extension of the nasal process of the superior maxilla; in the foregoing instances of absence of the lachrymal, the expanded plate of the nasal process which replaces it articulates posteriorly with the os planum of the ethmoid, and we have thus what we may term an ethmo-naso-maxillary suture. In the examples cited above, however, the frontal and orbital plate of the superior maxilla articulate with each other, and so cut off the expanded nasal process from contact with the os planum.

Another variety in the ossification of the inner wall of the orbit is the occasional division of the os planum into two portions—an anterior and a posterior. The anterior part varies much in relative size to the posterior; it is usually smaller, oftentimes so small that there may be doubt as to whether it is an ossiculum ethmo-lachrymalis or strictly ethmoidal in source. Of such division of the ethmoid I have seen four cases.

Fig. 1.



It appears, therefore, that in the production of the orbito-maxillary frontal suture (the term which I propose to employ to describe this suture), three factors require to be considered:—

(1) The presence of ossicula ethmo-lachrymalia, which, by fusing either with the superior maxilla or frontal, or both, may give rise to this anomalous suture (fig. 1, A, B, and C).

(2) Division of the os planum of the ethmoid into two parts, the anterior of which may unite with either the superior maxilla or frontal, and so produce the suture (fig. 2, A and B).

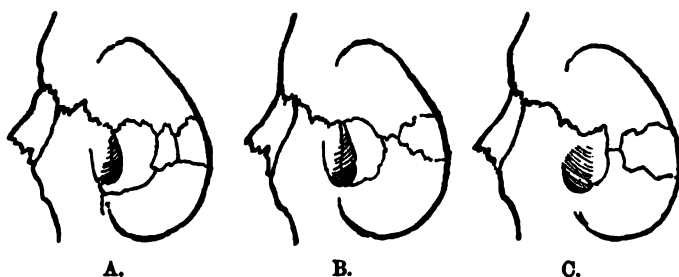
(3) Absence of the os lachrymale. In this variety the nasal process of the superior maxilla (which replaces the lachrymal bone) may not extend backwards sufficiently to articulate with

the os planum of the ethmoid, in which case we have the frontal and orbital plate of the superior maxilla coming in contact, and so producing the suture (fig. 2, c).

Of the first variety, the arrangement seen in the Patagonian and Solomon Islanders' cranium is an example (fig. 1, c).

Of the second variety, the appearance displayed in the orbit of a native of Darnley Island (fig. 2, A) is probably the earlier stage of such a condition, as is seen in the orbit of a Maori (fig. 2, B).

Fig. 2.



While the third variety is exemplified in the orbit of the Andaman skull (fig. 2, c). In the other instance of absence of the lachrymal bone there is a small quadrangular ossicle placed between the lachrymal plate of the nasal process of the superior maxilla and the ethmoid, which it is difficult to allocate precisely.

Professor Sir William Turner, in drawing attention to this anomalous variety of suture, says regarding it—"It marks a reversion to the pithecoïd arrangement, and is a sign of degradation of the human cranium; for in the Gorilla and other species of *Troglodytes* the os planum is triangular, and the frontal and superior maxilla articulate with each other between it and the lachrymal on the inner wall of the orbit."¹

In regard to the latter part of this statement, which was based upon the examination of several crania in the Anatomical Museum of the University of Edinburgh, I found, on examining the Gorilla and Chimpanzee skulls in the Oxford collection, that the results were not in accordance with the foregoing conclusion, as will be seen from the table subjoined:—

¹ "Challenger" Reports, *Zoology*, pt. xxix. p. 12.

GORILLA, 7 Specimens.

With Ethmo-Lachrymal Suture.	Doubtful.	With Orbito-Maxillary Frontal Suture. ¹
5 mm. wide. 7 mm. wide. 6.5 mm. wide?	3.	3.5 mm. long?

CHIMPANZEE, 7 Specimens.

With Ethmo-Lachrymal Suture.	Doubtful.	With Orbito-Maxillary Frontal Suture.
3 mm. wide. 6 mm. wide.	2.	2 mm. long. Just touching. 1 mm. long.

In two other specimens of the Chimpanzee the os planum of the ethmoid is divided; in one the anterior portion measures 2 mm. \times 7 mm.

In another specimen there is a difference between the two orbits, one side apparently having an ethmo-lachrymal, the other an orbito-maxillary frontal suture. Out of seven Gorillas examined, one only shows this latter arrangement of the suture, and even in this case there is some little doubt about it. In three cases the ankylosis is so complete that it is impossible to form any opinion in regard to the arrangement. In the remaining three skulls, the ethmo-lachrymal suture is present; to one of these I have affixed a note of interrogation, as there may be some doubt regarding it.

Of the ten Chimpanzee skulls examined, three display an orbito-maxillary frontal suture on both sides, one on one side only, two are doubtful, two have a divided os planum, and two have clearly defined ethmo-lachrymal sutures. Pursuing my inquiries further, I examined the orbits in seven Orang skulls. In no instance did I observe the occurrence of an orbito-maxillary suture, but in every case there was evidence of an ethmo-

¹ The term which, for brevity, I propose to apply to the condition where the orbital plate of the superior maxilla articulates with the frontal between the lachrymal and os planum.

lachrymal suture varying in width from 9 mm. (three instances) to a mere point of contact between the two bones.

Professor Macalister, in this connection describes the lachrymal of the Gorilla as possessing a short ethmoidal suture;¹ while Professor Flower, in discussing the differences between man and the other primates, says regarding the latter—"The os planum of the ethmo-turbinals always forms part of the inner wall of the orbit, *having the same relations as in Man*" (the italics are mine).²

From the above statements, it appears that there is still some difference of opinion with regard to the relation of the lachrymal to the ethmoid in the higher Apes. From my own observations, it would appear that both conditions, viz., that with an ethmo-lachrymal suture, and that with an orbito-maxillary frontal suture, occur commonly in the Gorilla and Chimpanzee; but from the small number of specimens I have been able to examine, it is hazardous to deduce any percentages. Nor are the specimens of Orangs inspected sufficiently numerous to enable us to state that the occurrence of an orbito-maxillary frontal suture may not be more common than the present data would lead us to suppose.

On the other hand, it appears from the facts already stated with regard to the occurrence of small ossicles in the ethmo-lachrymal suture, that the occasional presence of an orbito-maxillary frontal suture is precisely analogous to the anomalous condition sometimes observed in the region of the Pterion, where the squamous temporal may articulate with the frontal, forming a squamoso-frontal suture. In this region the occurrence of small ossicles in the sutures around the Pterion is by no means uncommon. These epipteric bones possess no morphological significance,³ and are to be regarded simply as the detached angles of the surrounding bones, most frequently the great wing of the sphenoid or the anterior inferior angle of the parietal; by the fusion of these separate ossicles with the frontal

¹ *Proc. Roy. Soc.*, xxxvii. 1884, p. 247.

² *Osteology of the Mammalia*, by W. H. Flower, LL.D., F.R.S., London, 1885, p. 161.

³ *Jour. Anat. and Phys.*, vol. xxii., 1887-88; *Proceedings of the Anatomical Society*, p. xxvii.; *The Pterion in different Races of Men*, Arthur Thomson.

anteriorly or the squamous temporal posteriorly, we have a squamoso-frontal suture formed in a purely accidental fashion, in proof of which I may add that in those races in which we have a narrow spheno-parietal suture, we do not find that the squamoso-frontal suture occurs much more frequently¹ than in the higher races with a wide spheno-parietal suture, a fact altogether contrary to what we would expect.

I trust I have been able to trace a similar cause as the explanation of the occurrence of an orbito-maxillary suture in man. The drawings given appear clearly to support this view; and whilst, as our information at present stands, the condition appears only to have been noticed in the crania of the lower races of man, it by no means follows that we might not meet with instances of its occurrence in skulls of the highest development. It likewise appears that such narrowing of the os planum as one constantly notices in the orbits of some races, Australians particularly, does not seem to exercise any influence on the more frequent occurrence of an orbito-maxillary frontal suture.

All things considered, it would appear that little reliance can be placed on the occurrence of such an orbito-maxillary frontal suture as evidence of a reversion, or a sign of degradation; we must rather regard its presence as due to purely accidental circumstances.

¹ I am aware that this view is not in accordance with the conclusions of some observers. I have examined a great number of skulls with the object of investigating this point, but for various reasons have as yet been unable to publish the results.

HUMAN NECK WITH THE ODONTOID PROCESS
DISTINCT FROM THE BODY OF THE AXIS
VERTEBRA. By Professor Sir WM. TURNER, F.R.S.

IN a paper communicated to this *Journal* in January 1886 (vol. xx. p. 238), Professor D. J. Cunningham of Trinity College, Dublin, gave an interesting account of the persistence in the human spine of a portion of the intervertebral disc between the odontoid process and the body of the axis, even up to an advanced period of life. The persistent part of the intervertebral disc could not be seen until a vertical section was made through the odontoid and axis, for the two were fused by bony union at the periphery of their plane of apposition. The oldest subjects in which the remains of the disc were seen were between sixty and seventy years.

Some months ago one of my pupils, Mr Percival Locke, obtained from a female subject apparently about fifty years of age, dissected in my practical rooms, an axis vertebra, in which the odontoid process was not in any way connected by bony union with the upper surface of the body of the axis, so that when the bone was macerated the two came quite asunder, and the process was therefore a true os odontoideum. It was observed that before maceration a distinct intervertebral disc was interposed between the superior surface of the body of the axis and the adjacent surface of the odontoid process. After maceration these surfaces were seen to have the following appearance. That of the axis was slightly convex and somewhat roughened. That of the odontoid was smooth and somewhat concave, and from its posterior border a buttress-like process sloped downwards and backwards in relation to the upper part of the posterior surface of the body of the axis. The anterior surface of the odontoid had a distinct articular facet for the atlas; but the posterior surface was roughened, and had no definite facet for articulation with the transverse ligament. In other respects the axis was normal.

The atlas presented one or two modifications worthy of notice. From the lower border of the anterior part of its ring immediately below the articular surface for the odontoid, a bony process,

8 mm. in vertical diameter by 9 mm. in transverse diameter, had grown vertically downward in front of the lower part of the odontoid and the upper part of the anterior surface of the body of the axis, with neither of which, however, it articulated. The interval between the inner surfaces of the two lateral masses of the atlas was at its narrowest transverse diameter only 12 mm., for internal to each superior articular surface the bone had grown in the direction of the neural canal, so as to leave no more of an interval than was required for the lodgment of the odontoid process. This portion of the atlas was rough both on its upper and inner surfaces, but below it formed a part of the broad inferior surface of articulation with the axis. The transverse ligament was attached laterally to the roughened part of the bone, and was unusually short.

Although the union between the odontoid process and the axis was in this specimen after the usual mode of junction between the bodies of two movable vertebræ, one may notice several provisions for giving additional security to the process, so as to some extent to stand in the stead of the customary ankylosis, and to give comparative fixity to the odontoid, as a pivot about which rotation of the atlas and head might take place. Thus the development of the buttress-like process of bone from the posterior border of the base of the odontoid, and that of the vertical plate from the lower border of the anterior part of the ring of the atlas, prevented displacement of the odontoid in the antero-posterior direction; whilst the narrowing of the interval between the two lateral masses of the atlas checked any tendency to lateral displacement. In all probability, therefore, in this person the rotatory movements had been performed almost as steadily as in a normal neck.

The separation of the odontoid from the body of the axis is also interesting from a morphological point of view, as showing how distinct they are in their development, and that the odontoid process is a true vertebral body. This specimen is therefore comparable in the relations to each other of the os odontoideum and axis with the condition which Cunningham has figured as a normal arrangement in the Marsupial genus *Thylacinus*.

The specimen is preserved in the Anatomical Museum of the University of Edinburgh.

A CONTRIBUTION TO THE PATHOLOGY OF JOINT BODIES. By R. GLASGOW PATTESON, B.A., M.B., *Assistant-Surgeon to St Vincent's Hospital, Dublin; late Surgical Travelling Prizeman, University of Dublin.*
(PLATE XV.)

THE obscurity which involves the pathology of loose bodies in joints is shown by the manifold theories which have from time to time been put forward to explain their occurrence. Putting aside "foreign" bodies, in the proper sense of bodies which have obtained entrance into a joint from external sources, and confining the term "joint bodies" to those developed in, or in connection with, a joint, the following classification embraces all the varieties I have been able to find described by the various authors who have written on this subject:¹—

1. *Fibrinous Bodies*.—The result of hæmorrhage or of fibrinous inflammation in a joint: the so-called "melon-seed" bodies (Hunter).
2. *Lipomatous Bodies*.—The product of hyperplasia of the sub-synovial fatty tissue (Orth), such as occurs in the condition described as lipoma arborescens (J. Müller); or of hyperplastic increase and subsequent fatty degeneration of the villi of the synovial membrane.
3. *Fibrous Bodies*.—Resulting from papillary hyperplasia and detachment of the synovial villi: the papillary fibroma of Virchow.
4. *Fibro-cartilaginous Bodies*.—The product of hyperplasia of islets of cartilage cells occasionally found in the villi of the synovial fringes (Rokitansky).
5. *Cartilaginous Bodies*.—Due to detached ecchondroses in arthritis deformans (Laennec), or to traumatic separation of a portion of articular cartilage (Bloch).
6. *Osteo-cartilaginous Bodies*.—A further development of the cartilage cells of the villi of the synovial membrane

¹ In this list I have, for the sake of brevity, omitted references to literature, but have, as far as possible, indicated in brackets the names of the earliest describers of the various conditions.

(Rokitansky, Virchow), or a nodosity which has become detached in joints the seat of chronic rheumatic arthritis (Brödie, Adams, Cruveilhier).

7. *Osseous Bodies*.—The result of separation by fracture of an osteophyte (Billroth).
8. *Traumatic Bodies*.—Portions of articular cartilage with a layer of subjacent bone, which have become detached by direct violence, and set free in the cavity of the joint (Teale, Marsh, Jacobson, Kragelund).
9. *Necrotic Bodies*.—Which occur when portions of the articular surface, either purely cartilaginous or with a portion of subjacent bone, have become sequestered by a process of "quiet necrosis," following a less degree of violence to the joint (Teale, Paget, Kragelund).

I am indebted to the kindness of my colleague, Mr M'Ardle, for the opportunity of examining and describing the accompanying specimen, obtained from a young man aged 24. Eight years previously he first noticed "something in his knee." It could then be felt at the inner side of the ligamentum patellæ, and was about the "size of a small pea." It used occasionally to slip in between the articular surfaces, giving rise to the characteristic train of symptoms. There was no history of antecedent injury or of rheumatic pain. In this situation it gradually increased in size, and three years ago, when it had increased to the size of a bean, he dislodged it from this position himself, pushing it upwards into the joint in the hope of obtaining permanent relief. Disappointed in this, and the body still continuing in growth, he sought admission into St Vincent's Hospital. The body was found lying in a pouch of the synovial membrane, above and to the inner side of the patella. The operation was performed a few days later by Mr M'Ardle, the body being displaced to the outer side of the joint, and removed by direct incision. The patient made an excellent recovery.

The body, on examination, was found to be of an irregularly oval shape, reminding one somewhat of a small patella. It presented one entirely cartilaginous surface, and one composed of a bony centre with a surrounding cartilaginous rim (fig. 1, A, B). Its cartilaginous surface was smooth and glistening, showing only a few slight depressions; the bony surface was rough and

irregular, and raised above the marginal collar of cartilage, which at one border was almost hidden by the overlying ridge of bone. It measured in length 28 mm., in breadth 22 mm., in thickness 11 mm. A median section showed it to be composed of an oval bony nucleus, covered on one side by a crescentic disc of cartilage (fig. 1, c.). The greatest thickness of bone was 8 mm., of cartilage 4 mm. The bone was of a yellowish colour, and of denser structure than normal spongy bone. At the point seen in section, the uncovered surface of bone was only slightly mammillated; but in other parts it presented a rough and uneven surface, the hollows being filled with fibrous tissue, while on the projecting bony points distinct evidences of eburnation could be seen. There was no hilum, and at no part could any traces of a pedicle be found.

On microscopic examination the cartilaginous surface was seen to be completely invested with an envelope of cellular fibrous tissue (fig. 2, A.), which also extended over the margins of the bony surface, filling the interstices between the trabeculae, and dipping into, and at times completely filling, the neighbouring medullary spaces. Beneath this the cartilage presented all the characters of articular cartilage, except that cell-division was over-active in the intermediate or middle zone. Most superficially placed was a layer of cells lying in a homogeneous intercellular substance, and arranged parallel to the surface, the primary and secondary capsules being distinctly seen (fig. 2, A.). Below this lay a zone of irregularly-grouped round or oval cells, much broader than that found in ordinary articular cartilage. These cells possessed a distinct contour, a deeply-staining nucleus, and well-defined capsules, the matrix in which they lay being slightly fibrillar and more or less infiltrated with lime-salts between the cell territories (fig. 2, B.). Beneath this layer, and arranged perpendicularly to the underlying bone, was a third, or osteogenetic layer, the cells of which had mainly lost their capsules, and lay embedded in a finely granular and, for the most part, calcified matrix (fig. 2, C.). In one or two limited spots the bony trabeculae were undergoing a retrogressive metaplasia into a cartilaginous-like tissue.

In further considering this subject, it is my intention on the present occasion to deal with only two of the many questions

of pathological interest suggested by the study of this body—firstly, as to its mode of origin; and secondly, as to its mode of growth.

I. *Mode of Origin.*—In this case we can absolutely exclude a traumatic causation, either direct or by a process of slow exfoliation. Although the possibility of traumatic causation is denied by Ollier,¹ and regarded by many others with scepticism, notably in these countries by Professor Humphry,² it can hardly be longer doubted after the numerous clinical instances which have been recorded both here and on the Continent, and which attest the reality of its occurrence.³ Excluding traumatic causes, one thing is certain, that loose bodies can only occur in a joint more or less diseased, and often afford the only evidence of a pre-existing affection of the joint. Laennec regarded them as, in many cases, extra-articular formations, which resulted from recurring attacks of synovitis, and which subsequently found their way into the joint. If such an origin is possible, it must at least be one of very rare occurrence. The most generally accepted theory is that of their derivation from the synovial fringes. Since Kölliker demonstrated the occasional presence of cartilage cells in the villi of the synovial membrane, quite an exaggerated share has been allotted them in the pathology of joint diseases. Rokitsansky⁴ first put forward the theory of their causal relation to joint bodies of osteocartilaginous nature, to the exclusion of every other cause. To a certain extent his view has been adopted by Virchow,⁵ and following him the majority of writers have accepted the presence of these isolated cartilage cells as a circumstance which adequately accounted for

¹ *Dict. Encycl. des Sciences Méd.*

² *Brit. Med. Journal*, September 29, 1888, vol. ii. p. 707.

³ *Vide* Simon, *Path. Soc. Trans.*, vol. xv. p. 206, 1865; Teale, *Brit. Med. Journal*, May 26, 1888, vol. i. p. 1109; Jacobson, *Operations of Surgery*, note on p. 1032; and the two cases in the article by M.M. Poulet and Vaillard subsequently referred to. Virchow, after adverting to the comparative infrequency of loose bodies of traumatic origin in healthy joints, refers to those cases in which correspondence in shape and size between the body and the lesion of the joint surface exists so exact that it is hard to conceive it as a result of pressure-absorption, and concludes: "Les faces se correspondent parfois si parfaitement et sont si profondes, que l'on peut à peine se refuser à admettre leur connexion primitive," *Traité des Tumeurs*, tome i. p. 454.

⁴ *Zeitschrift der Wiener Aerzte*, January 2, 1851.

⁵ *Die Krankh. Geschwülste*, Bd. i., Berlin, 1863.

all the varieties of joint bodies. Though no doubt exists that they do give rise to certain forms of bodies, and every step from commencing development, through the stage of pedunculation, and so to complete freedom, may be at times observed in a single joint, yet we must remember that Kölliker himself admits that these cartilaginous centres occur but rarely, and subsequent observers have failed to find them in healthy joints. Accordingly we must not attribute to them an exaggerated rôle in the production of joint bodies, to the exclusion of other, at least equally probable modes of origin.

Sir Benjamin Brodie¹ seems to have been the first to recognise the important part played by chronic rheumatic arthritis as a factor in the production of osteocartilaginous bodies. His observation is worth quoting. "In cases in which the joint has been long the seat of disease (especially of that which I have described under the name of rheumatic gout), it occasionally happens that a bony ridge is formed, like a small exostosis, round the margin of the articular cartilages. In the two cases to which I allude this preternatural growth of bone had taken place, and in consequence of the motion of the parts on each other, portions of it had been broken off and lay loose in the cavity of the joint." Cruveilhier² regarded this as the most frequent mode of origin, but it is only of late that the full significance of the relationship has been determined. This has been embodied in a most valuable and exhaustive article by MM. Poulet and Vaillard, based on an extensive series of pathological and experimental researches, which throw a flood of light on this much-debated subject.³ They examined six cases of pedunculated, but freely movable bodies, from joints affected with

¹ *Path. and Surg. Observations*, 5th ed., p. 261, 1850.

² "Ils ne sont autre chose que des végétations, des ostéophytes, des ostéochondrophytes, des chondrophytes, ordinairement sphéroïdaux, toujours lisses lorsqu'ils sont cartilagineux, lisses ou tuberculeux lorsqu'ils sont osseux. . . . Dans le plus grand nombre des cas, ils ne sont autre chose qu'une végétation ou production osseuse née du pourtour des surfaces articulaires," Cruveilhier, *Traité d'Anat. Pathol.*, tome ii. pp. 135, 136, Paris, 1852.

³ "Contrib. à l'étude des Corps étrangers ostéocartilagineux et osseux des Articulations," par MM. Poulet et Vaillard, *Archives de Physiol.*, v., 1885. This article seems to have been strangely overlooked, and to it I am largely indebted for the foregoing facts and statements on which subsequent conclusions are based.

chronic rheumatic arthritis. All consisted of bone and cartilage, and all proved to be developed from osteophytes which had undergone varying degrees of separation. The similarity of their structure to that of two loose bodies, which originated after injuries—one in the elbow and one in the knee—led them to examine the mode of development of the osteophytes which are found in this diseased condition of joints. On examining them they found that there exists on the surface a primary fibrous envelope, which is continuous with the periosteum of the epiphysis on the one side and with the reflection of the synovial membrane on the other. In the centre of this projecting nodule of articular cartilage there is developed a bony nucleus, formed of trabeculae of varying degrees of density, which are more or less in continuity with the cancellous tissue of the epiphysis by means of slender processes of bone which traverse the cartilaginous neck of the osteophyte. Should fracture or pathological separation occur through this neck, the detached fragment will, after partial absorption of its base, and extension of the fibrous capsule over it, present all the characters of an osteocartilaginous joint body. In this way the authors account for the appearance of these highly-organised bodies shortly after the occurrence of an injury to a joint, as it is no uncommon occurrence for such a body to be found immediately after the subsidence of the accompanying synovitis. In order to compare the changes undergone by portions of articular cartilage and bone in healthy joints after mechanical separation, they undertook experimental observations on animals. The elbow-joint was opened, and a small portion of the articular cartilage and its underlying bone chipped off with mallet and chisel from the head of the radius. The detached fragment was fixed in the anterior part of the joint, and the wound closed with strict antiseptic precautions. Observations were made on three dogs after a lapse of 37, 43, and 123 days respectively from the time of operation. In all cases it was found that adhesions had been formed with the synovial membrane, in one case by the whole extent of the bony surface. Alterations, indicating active progress in the direction of absorption, were found in every case—fibrous transformation of the cartilage and medulla, and gradual destruction of the bony framework by

direct fibrous metaplasia, by pericorpuscular absorption, and by the lacunar erosion of Howship. These appearances were in striking contrast to those noticed in the free bodies, which, living only by imbibition, showed uniformly retrogressive changes of tissue in the direction of a more embryonic type, such as transformation of bone and medulla into cartilaginous tissue. But it is possible that in their experimental observations these active changes may have been determined by inflammatory reaction in the joint, so that too much importance should not be attached to them. But their observations show conclusively the identity of structure which exists between "loose bodies" and wholly or partially attached osteophytes in rheumatic arthritis.

In order to determine the causation of loose bodies, Kragelund examined the joints from thirty cases.¹ In eighteen he found well-marked signs of chronic rheumatic arthritis, and he regards this condition and traumatism as the chief factors in their causation. He recognises two forms of traumatic bodies: those resulting directly from the injury, and those produced, after a longer or shorter interval, by a process of localised necrosis determined by a limited inflammation (*Quiet Necrosis* of Paget).

Taking, then, all these facts into consideration, in conjunction with the microscopic characters of the specimen described above, I have no hesitation in regarding it as a product of chronic rheumatic arthritis. Objection may be made to the age of the patient and the absence of previous symptoms. MM. Poulet and Vaillard direct special attention to the latent character of this variety of the disease, which will not surprise any one acquainted with its Protean peculiarities. "In contradistinction to the common rheumatic arthritis," they remark, "it is a variety which may occur in young subjects, may be limited to single articulations, and localised to a single spot in it."² In the present case, the eburnation of the exposed bony surface, the limiting fibrous capsule derived from the reflection of the synovial membrane, the marked proliferation of the middle zone of cartilage, some of the capsules containing eighteen or twenty cells, as well as the pathological changes

¹ Kragelund, "Graduation Thesis," Copenhagen, 1886. Quoted in *Virchow und Hirsch's Jahresbericht*, 1887.

² *Vide* also Virchow, *Traité des Tumeurs*, tome i. p. 457.

exhibited (though in slight degree) by the medulla and bone, all agree with this theory of its origin. No other hypothesis affords at all as satisfactory a solution of the difficulty.

II. *Mode of Growth*.—I shall now only briefly allude to this, the second question which suggested itself for consideration. In the case of pedunculated or partially-separated bodies, or in those which having been free have again formed connections with the synovial membrane, no difficulty presents itself—they draw their supplies from the general circulation. But that bodies dependent for all supply on the synovial fluid should not only preserve their vitality but show signs of active increase, has been regarded by many with incredulity, and has led to very opposing views. Sir Astley Cooper absolutely denied the possibility of its occurrence; his contemporary, Russell, as strongly affirmed it. Von Recklinghausen¹ accepts the theory of their increase in size; and Virchow, after exposing the fallacy which may attend the sudden conglomeration of several small bodies, thus simulating the rapid growth of one, adds—"Theoretically, one cannot oppose any objection to the persistence of a lowered, if not an active, vitality in the detached portions of cartilage or bone. Not only can they obtain from the synovial fluid materials sufficient for their nutrition, but they can also increase in size."² The majority of French writers refused to accept the theory. Poncet says—"Everything tends to prove a slow but gradual resorption of the arthropytes; nothing justifies us in concluding that they can increase by proliferation of their elements."³ But that this does not always hold good

¹ *De corpor. lib. Articulorum*, 1864.

² And, in further support of its probability, he adds, "Car, dans le fait, les pédicules, en tant en général qu'ils ne sont pas détachés, sont aussi ordinairement peu vascularisés, quoiqu'ils ne manquent pas toujours de vaisseaux, et cependant les corps s'accroissent" (Virchow, *loc. cit.*, i. p. 459). And Billroth, in a passage bearing on this point, remarks: "Die viel häufigere Art der Entstehung von Gelenkmäusen ist aber die, dass sich in der Gelenkkapsel dicht unter der Synovialmembran verknöchernde Knorpelkörper (Osteophyten) bilden, welche sich ins Gelenk hineinstülpen, die Synovialis vor sich herschieben, stielartig ausziehen, die schliesslich aber abreißen und frei werden können. Wahrscheinlich wächst der frei in Gelenke liegende Körper nicht mehr; undenkbar wäre es freilich nicht, dass er sein Ernährungsmaterial aus der Synovia zöge" (*Allgem. Chirurg. Patholog. u. Therapie*, Billroth u. von. Winiwarter, s. 702, Berlin, 1887).

³ *Revue de Chirurgie*, 1888, p. 819.

is proved by the case before us. We are fortunate in having a definite history, extending over a period of eight years. Of the first five years of its existence we can affirm nothing; but it is probable that, as it lay beside the ligamentum patellæ, it was attached either to the bone or by secondary adhesion to the synovial membrane, and was drawing its supplies from the blood. But when, three years ago, the patient pushed it up into the joint, that attachment must have been ruptured to allow of its travelling so far. It was then the size of a bean. At what exact time it found a resting-place in the supra-patellar pouch we do not know, but it had lain there for a considerable time, and continued to increase in size until it was removed, yet no trace of any attachment or of a pedicle could be seen. Here is evidence, not merely of preserved vitality, but of fairly active growth—in three years it has at least doubled in size. Microscopic examination also confirms this, and disproves the accuracy of M. Poncet's statement. The cells show a distinct contour, possess a sharply-defined nucleus, and in their reaction to staining agents behave as living cells. Moreover, in many parts they are in a state of undoubtedly active proliferation. These characters do not belong to enfeebled or merely existing tissues—they are peculiar to living, active growth.

To summarise the conclusions based upon an examination of the foregoing facts:—

1. In the majority of cases, loose bodies of mixed cartilaginous and bony nature are *wandering osteophytes*, and are evidences of a rheumatic arthritis, either manifest or latent.
2. This form of chronic rheumatic arthritis is insidious and latent in many instances, occurs in young persons as well as in those more advanced in years, is often limited to a single joint, and is chiefly manifested in "lipping" of the margins of the articular cartilages, and in the formation of ecchondroses and osteophytes, which while attached cause no symptoms.
3. These bodies, after liberation in the joint, may, and do often, undergo considerable increase in size, living by imbibition, and their nutriment being derived from the synovial fluid. This fact points to the necessity of their early removal by operative interference.

ABNORMAL REPRODUCTIVE ORGANS IN *RANA TEMPORARIA*. By OSWALD H. LATTER, B.A., *Tutor of Keble College and Assistant to the Deputy Linacre Professor*. (PLATE XVI.)

DURING September of the present year, in the course of the ordinary laboratory work of the Anatomical Department in this Museum, a male Frog was met with, presenting certain peculiarities akin to those described in this *Journal* by Professor Milnes Marshall (xviii, 1884, pp. 121-144, pls. vi. and vii.) and by A. F. S. Kent (xix, 1885, pp. 347-350, pl. xviii.)

The present specimen, however, represents a stage of hermaphroditism which, as far as I can ascertain, has not yet been described in the Frog. The female organs are less markedly developed than in any examples hitherto figured. The hermaphroditism is, however, placed beyond dispute by microscopic examination. Unfortunately the abnormality was not discovered, owing to accidental delay, until the Frog had been dead for more than one day; consequently, the minute structure of the tissues is not satisfactorily preserved.

The general appearance of the organs in question is shown in fig. 1, Pl. XVI. The testes of the two sides are very dissimilar. The left testis is very long in proportion to its width, being almost as long as the kidney, and is subdivided into two parts by a broad transverse constriction at about $\frac{1}{3}$ of the entire length of the organ from the anterior extremity. The right testis is of the normal shape, but somewhat smaller than usual. The two testes are but very faintly pigmented. The fat bodies (not shown in figure) presented no unusual features. The ureters are swollen out, at the points where they become free from the kidneys, into the usual vesiculæ seminales, of which the left is somewhat the larger.

Attached to the posterior and outer border of each vesicula is a swollen end of a tube—the Müllerian duct. The right and left Müllerian ducts do not agree with one another either in size or internal structure. Both extend forward as far as the

base of the lung (*i.e.*, to the normal position of the open internal mouth of the Müllerian duct of the female); both are simple straight tubes, or rather cords, entirely devoid of all convolutions. The left Müllerian duct is a well-developed structure, being about twice the width of the Wolffian duct. The right duct is smaller, and is about the same size as the Wolffian duct. Both ducts run along the outer border of their respective kidneys, to which they are attached by numerous fine and darkly pigmented cords (see fig. 2).

I was unable to find any aperture into either of the ducts anteriorly, but there is little doubt that the swollen posterior portion of each duct corresponds to the uterine dilatation of the Müllerian duct of the normal female Frog.

Having carefully examined the organs as they lay *in situ*, I removed both testes, the Wolffian ducts with the vesiculæ seminales, and about half an inch of the Müllerian ducts attached to the last named, and also the anterior portion of the Müllerian ducts. Sections were cut of all these organs, with the following results:—

The Müllerian duct of each side is solid in its anterior portion, and has no opening anteriorly into the body cavity. The histological characters of the ducts could not be made out owing to bad preservation. The right duct has a small lumen posteriorly passing a little distance into the substance of the vesicula seminalis. The left duct has posteriorly a considerable lumen, widening out into a sinus inside the posterior portion of the vesicula, and passing through the substance of the vesicula, to come into wide communication with the lumen of the Wolffian duct (see fig. 6). The sinus is considerably broken up by irregular processes of the vesicula, appearing as islands in the section which I have diagrammatically represented.

The testes both present features in many respects similar to those of "Frog B," described by Professor Milnes Marshall (*loc. cit.*, pp. 127–131). There occur in both the right and left testis "ova" apparently replacing the seminal tubes. None of these "ova" are associated with pigmented cells. Their average dimensions are about 0.45 by 0.25 mm. The minute structure is closely similar to that described by Professor Marshall. Each ovum is enclosed in a fine capsule of connective tissue (see fig.

4 c); the capsule is hardly ever completely filled by the ovum, but fine threads stretch across the space separating the ovum from the wall of the capsule, leading one to conclude that considerable shrinkage has taken place. The matrix, nucleus, and nucleoli are in every way identical with Professor Marshall's specimens, and need not be further described.

A few of the ova are, however, remarkable as being situated *within* seminal tubes. This variation occurs in both testes, but not abundantly in either. I have figured an ovum of this kind in fig. 5. It will be seen that the "ovum" itself is smaller than ordinary "ova," but in other respects similar. The connective tissue capsule is difficult to make out in many cases, but I am inclined to think that it is always present. Outside the ovarian capsule is the remnant of an ordinary seminal tube containing a few spermatospores and also a large number of cells which appear to have broken down and undergone a partial degeneration. Of this degeneration I cannot speak with confidence, on account of the faulty preservation of the specimen; but I have not detected the same appearance in other seminal tubes to nearly so great an extent.

In conclusion, this Frog appears to be in a condition of hermaphroditism different from those described by Professor Marshall. The Müllerian ducts are less developed than in any of his specimens, but the testes are intermediate between those of his Frogs A and C, which are normal, and those of his Frog B, which possess more fully developed "ova" than the specimen I have described.

November 1889.

EXPLANATION OF PLATE XVI.

Alphabetical List of Reference Letters.

<i>c</i> , connective tissue capsule of ovum.	<i>n'</i> , nucleoli.
<i>c'</i> , connective tissue capsule of seminal tube.	<i>o</i> , ovum.
<i>d</i> , degenerate cell masses.	<i>r</i> , rectum.
<i>k</i> , kidney.	<i>sp</i> , spermatospores.
<i>ml</i> , left Müllerian duct.	<i>tl</i> , left testis.
<i>ml'</i> , lumen of Müllerian duct.	<i>tr</i> , right testis.
<i>mr</i> , right Müllerian.	<i>ur</i> , Wolffian duct.
<i>n</i> , nucleus.	<i>ur</i> , lumen of duct.
	<i>v.s</i> , vesicula seminalis.

Fig. 1. General view of genital organs, after removal of alimentary canal, fat bodies, &c.

Fig. 2. Kidneys, Wolffian ducts, vesiculæ seminales, and posterior portion of Müllerian ducts. Testes have been removed. The fine cords connecting the Müllerian ducts to the kidneys are shown.

Fig. 3. Enlarged view of testes and kidneys, with portion of Wolffian duct.

Fig. 4. Section of normal "ovum."

Fig. 5. Section of "ovum" within seminal tube.

Fig. 6. Diagram of longitudinal horizontal section through left Müllerian duct, vesicula and Wolffian duct, showing communication of the two lumina.

ON FIBRO-PLATES AND INTERVERTEBRAL DISCS.

By Professor CLELAND.¹

THE intervertebral discs and those fibrous plates with smooth surfaces found in some of the synovial joints are habitually spoken of together as both being examples of fibro-cartilage. The object of the following remarks is to show how thoroughly they differ if each be looked on as a single substance; while, on the other hand, it will be contended that both the intervertebral discs and the interarticular fibro-plates consist of a synovial and a fibrous part, and that the word fibro-cartilage is used in quite a different sense when applied to the synovial part of the disc and the fibrous interior of the fibro-plate.

The history of the term fibro-cartilage is curious and worthy of attention. In Bécclard's *Elements of General Anatomy*, translated by Knox (p. 238), occurs the following:—

"Galen has named certain ligaments neuro-chondroid, *νευρο-χονδρωδες συνδεσμοι*; Vesalius calls them cartilaginous ligaments; Morgagni considers them intermediate between the ligaments and cartilages; Weitbrecht comprehends them among the ligaments; Haase, on the contrary, arranges them in his chondrology, under the names of ligamentous and mixed cartilages. Bichat has proposed a fibro-cartilaginous system, composed of the cartilaginiiform ligamentous tissue of which we here speak, and a part of the cartilaginous tissue."

As neuro-chondroid and fibro-cartilaginous are but Greek and Latin renderings of one expression, the word fibro-cartilage may be said to have come from Galen; and it has, therefore, been in use for ages without reference to anything so modern as microscopic anatomy.

But it has gradually come about that the word now conveys two ideas, one that of a substance with physical characters intermediate between those of cartilage and fibrous tissue, the other that of a texture consisting of fibres with cartilaginous elements imbedded; and these ideas are not necessarily descrip-

¹ Read before the Anatomical Society, February 1890. The paper was illustrated by microscopic slides.

tive of identical substances. The interarticular fibro-plates are fibro-cartilage according to the one definition, while the nucleus gelatinosus of an intervertebral disc, a structure very different in appearance, complies microscopically with the other.

A reference to the last five editions of *Quain's Anatomy* will help us to appreciate the present state of opinion. Sharpey, in the fifth edition, gave expression with his usual clearness to the prevalent idea that the tissues named fibro-cartilage are "a mixture of the fibrous and cartilaginous tissues," and that "the proportion of the two elements varies exceedingly in different instances." He left the description unaltered in the sixth and seventh editions, and the only point in regard to which I question its complete accuracy is that it leads to the belief that the corpuscles found in interarticular fibro-plates are, at least some of them, cartilage-corpuscles. In the eighth edition, under additional editorship, "fibro-cartilage" is changed to "white fibro-cartilage" at the head of the article, and the only other change is a suggestion that "it is probable that the matrix is at first hyaline, and that fibrous tissue is subsequently developed within it," a statement calculated to mislead. In the ninth edition Schäfer makes further changes, and tells us that fibro-cartilage appears to be made up of "wavy fibres like those of ordinary ligament, with cartilage cells occupying the place, and often simulating the arrangement of tendon-cells." He states further that they are "somewhat flattened where the bundles of fibres are closely packed."

These descriptions are quite inapplicable to the interarticular fibro-plates, but had they been made in reference merely to the structure of intervertebral discs they would, perhaps, have called for little comment, although even in the intervertebral discs in the human subject the somewhat flattened cartilage corpuscles arranged in rows between the slanting fibres are, especially when seen in their natural condition, unshrivelled by glycerine or varnish, quite distinct from the corpuscles of tendon. They are occasional and imbedded, not arranged regularly throughout the whole structure.

Previous to the ninth edition of *Quain's Anatomy* appeared the *Atlas of Histology*, by Klein and Noble Smith; and in it (plate xi.) figures are given of the laminated part of the inter-

vertebral disc of a mouse, exhibiting elongated nuclei in regular linear series extending throughout the tissue, each nucleus resting on an area which, as figured, might pass for one of the quadrate tendon cells of Ranvier, while the nuclei themselves quite correspond in appearance with the elongated nuclei in chains in tendon, as I have described them in Memorandum 24 of *Memoirs and Memoranda in Anatomy*, vol. i. The structures so figured are, however, described as "cartilage cells arranged in rows."

In the discs of the rabbit's tail, I find that most superficially there is true tendinous structure, and that, a little deeper, there are rows of cartilage-corpuscles much more regularly placed than in the human subject, and extending between the fibres in their whole length. They may be said to answer to Schäfer's description in the passage quoted, but they do not at all correspond with Klein's figures of what is to be found in the mouse. They have not the elongated nuclei which are present in the most superficial layer. So also in the human subject, in the lumbar region, the outermost layers of the discs are furnished with the elongated nuclei of tendon, while those immediately subjacent have, instead, cartilage corpuscles imbedded. I show a preparation of the tendon of the superior rectus muscle of the eyeball, with the elongated nuclei, to compare with those from the outermost layers of the lumbar discs. It is, however, noteworthy that while the outermost layers have chains of elongated nuclei and no cartilage corpuscles whatever, those immediately subjacent to them show cartilage corpuscles linearly arranged, and have not got, so far as I can see, the elongated nuclei at all; and as we pass inwards from lamina to lamina we find the cartilage-corpuscles arranged in less distinctly linear fashion, until in the nucleus gelatinosus, as every one knows, the groups are altogether irregular, isolated, and in clusters. It is especially in this central part that withered corpuscles in laminated capsules are found.

We turn now to the interarticular fibro-plates. That their main structure is fibrous none can doubt. It is towards their surfaces and edges that other structures can be demonstrated. It was in the temporo-maxillary plate of a Puma that I first observed a large number of broadly oval nuclei, around some of

which I could detect a small amount of protoplasm. These nuclei come out very distinctly with carmine, and they have not the very smallest resemblance to cartilage-corpuscles. They are identical with large oval nuclei which are to be found beneath the surface of synovial membranes. I have found them in vast abundance and of large size in a specimen before me from the fold at the mouth of the subscapularis bursa leading from the shoulder-joint, also in the joints at the knuckles. But in the substance of the fibro-plates what strikes one is the abundance of the elongated tendon-nuclei, mostly separate, sometimes joined by a thread end to end; and among these may always be detected others more broadly oval and flattened, representing, as it seems to me, the circular nuclei which may be seen in the substance of the quadrate scales of the tendons in a rat's tail. This structure I have made out in the semilunar plates of the knee and the triangular radio-ulnar fibro-plate.

In connection with the fibro-plates are often to be found synovial villi or fringes, processes simple and branched such as occur in many places in the interior of joints, and are well known, being figured, for example, by Henle ("Bänderlehre," p. 10).¹ These synovial appendages are known to present a variety of histological appearances. Henle figures two varieties—one without and the other with imbedded groups of round corpuscles. Both are common. So also are those in which the corpuscles are like those of cartilage, and exactly similar to what may be found in the intervertebral discs.

In a specimen taken from a perforated sterno-clavicular plate, which was covered with villous growths, I am fortunate enough to find one of these processes already assuming the appearance of a block of cartilage, remaining adherent by a slight pedicle of delicate tissue, illustrating beautifully the mode of origin of loose cartilages in joints. So also, in connection with a radio-ulnar plate, I have found a depression filled with villous processes, and among them two small calcified cartilages completely loose.

This whole subject had a flood of light thrown on it thirty-two years ago by Luschka in his splendid monograph, "Die

¹ A villous fringe is always to be found at the free margin of the semilunar plates of the knee-joint.

Halbgelenke," too shortly alluded to in a paragraph introduced into the 7th edition of *Quain's Anatomy* and continued in the subsequent editions, but practically ignored by many anatomists, who, not grasping Luschka's discovery, have allowed it to sink too much into oblivion. The discovery to which I allude may be summarised thus:—Luschka appreciated that, in the development of the complete joints, the substance of the synovial membrane made its appearance first, and afterwards presented a cavity which it surrounded on all sides, and that, not till a later stage of growth, did the articular cartilages become bare; and, finding that the intervertebral discs presented cavities in their interior, into which processes of simple and branched forms projected, and that the tissue of the nucleus gelatinosus was similar to the synovial fringes in other joints, which frequently have nested cartilage-corpuscles within them, he concluded that the discs were to be looked on as synovial capsules filled up with fringes, instead of going on to that more complete stage of articular development in which the synovial membrane disappears from the opposed faces of the cartilages.

We have thus two structures present in a complete joint and two in an intervertebral disc, synovial tissue and fibrous capsule. It is the synovial tissue which has the curious relationship to cartilage, exhibited by the occurrence of cartilage-corpuscles occasionally in the fringes of perfect joints, and constantly in the substance of the discs; and it seems clear that this cartilaginous growth within synovial tissue is not derived from the cartilages around it, but from some peculiar potentiality of the tissue itself, as evinced by its occurrence in fringes of late growth and far removed from articular faces of the joint, while the intervening texture has only unencapsuled corpuscles or nuclei in it.

In the interarticular fibro-plates there are only these free corpuscles, and thus I can see no bond of connection between fibro-plates and intervertebral discs, entitling them to be spoken of together under the name of fibro-cartilage, unless we are prepared to include all synovial membrane under the name, which would be obviously absurd. Looking to the mere histological facts, there is no refusing the name fibro-cartilage to the deeper part of the laminated portions of the intervertebral discs, while

there is no histological connection between cartilage and the fibro-plates. These owe their physical characters to an intricate intertwining of white fibres, so matted together that the structure cannot be torn in one direction more easily than another; and, although at their surface they may lose all trace of this matter structure, the homogeneous material there situated, in which the deeper fibres are lost, is still completely different from cartilage, both as regards its corpuscles and its matrix.

Altogether it must be confessed that the use of the term fibro-cartilage at the present day is very liable to lead to confusion and the confounding of structures essentially different; while, on the other hand, there is no difficulty in getting on without it; and, certainly, for the designation of the interarticular structures sometimes called cartilages, sometimes fibro-cartilages, and sometimes laminæ or menisci, the word fibro-plate which I have used in this communication seems best to combine the qualities of accuracy and definition.

A CONTRIBUTION TO THE PHARMACOLOGY OF
CURARE AND ITS ALKALOIDS.¹ By JOSEPH
TILLIE, M.D., *Assistant to the Professor of Materia
Medica in the University of Edinburgh.* (PART I.)

IN this paper I propose to show specially, among other points, that the pure alkaloid curarine, in addition to its paralysing action on motor nerve ends, produces tetanus; and that also all specimens of curare have a tetanising action on the cord.

The *curare* or *wourali arrow poison* of South America has for a long time occupied quite a special position in the physiological and pharmacological laboratory as an aid in experimental research. Yet, although a very large number of papers, dealing at length with its actions, have been published in the physiological literature of the last thirty-five years and earlier, there are still some important points on which there is complete difference of opinion; and, on the other hand, some important points are held to be firmly established, although, as will be seen, unsupported by evidence which is free from fallacy.

Especially after Claude Bernard's observations were made on curare in 1844, it was universally agreed by many investigators that the poison interrupted in some way the conductivity of a part of the endings of the motor nerves distributed to striped muscles.

Almost all those early writers further concluded that curare did not paralyse the endings of sensory nerves. Several of them, however, came to the opposite conclusion, and in this they are strongly supported by several recent authors.

¹ This paper is an abstract of part of a thesis presented to the Medical Faculty of the University of Edinburgh in April 1889 for graduation as Doctor of Medicine, to which was awarded a gold medal and the Christison (Gunning) Prize.

The main part of the work was done in the Pharmacological Laboratory of the University of Leipzig in 1887-88 while holding an Edinburgh University scholarship. The experiments with crude curare, the bark of *Strychnos toxicaria*, and some of those with methyl-strychnium salts were carried out in the Pharmacological Laboratory of the University of Edinburgh in 1888-89.

Some investigators and authors who state that the sensory nerves are depressed or paralysed by curare.		Some investigators and authors who state that the sensory nerves are not affected by curare.	
	Date.		Date.
Schiff (10),	1865	Bernard (1),	1857
Boehlendorff (11),	1874	Kölliker (2),	1856
Lange (12),	1876	Vulpian (3),	1854-9
Romanes (14),	1877	Martin-Magron and Buisson (4),	1859
Steiner (13),	1884	Pelikan (5),	1857
Binz (15),	1887	Haber (6),	1859
Lauder Brunton (16),		Von Bezold (7),	1860
		Kühne (8),	1860
		Bidder (9),	1865

On the important question of the action on the spinal cord of a poison, whose chief active principle is derived from the strychnos family of plants, less, but equally emphatic, difference of opinion is to be found.

The great majority of writers are agreed that curare has no "stimulant" or tetanising action on the spinal cord. But, while several consider that the poison has no action, the general opinion is that the experimental evidence is very distinctly in favour of a paralysing action. On the other hand, some of the early writers are equally clear that curare has a "stimulant" or strychnine-like action.

Some investigators and authors who state that the spinal cord is either unaffected or is paralysed by curare.		Some investigators and authors who state that the spinal cord is "stimulated" or acted upon in a strychnine-like manner by curare.	
	Date.		Date.
Bernard (1),	1857	Wundt and Schelake (19),	1859
Kölliker (2),	1856	Martin-Magron and Buisson (4),	1859
Haber (6),	1859	Von Bezold (7),	1860
Bidder (9),	1865	Vulpian (3),	1862
Foster (17),	1873		
Rutherford (18),	1880		
Brunton (16),	1887		
&c.			

Confining attention, meanwhile, to the action on the sensory nerves and spinal cord, it may at once be suspected that there are some serious difficulties or fallacies in the investigation, otherwise, the experimental evidence detailed by distinguished physiologists on either side would not be so contradictory, and so many authors would not, time after time, arrive at different conclusions.

A serious objection to the employment of only crude curare in any kind of precise work is the circumstance that the poison is not an individual chemical body, but a more or less impure

compound vegetable extract of variable strength, composition, and origin. There is no security, therefore, that curarine is the only alkaloid present. Indeed, this objection has been emphasised quite recently by Boehm (20), who has shown that, in some varieties of curare, the alkaloid curarine is associated with another alkaloid, which he has named curine. Without a pure curarine there could be no decision free from an element of uncertainty; but it may at once be stated that the different views of the action of the poison on sensory nerves and the spinal cord are not to be explained by chemical differences in the curares, but by the fallacies caused by the actions of the poison itself.

A pure specimen of curarine, recently prepared and very kindly supplied to me by Professor Boehm, was first employed. As a preliminary to the investigation, the poisonous activity and general action of the alkaloid were determined.

In the frog, the minimum dose by subcutaneous injection which could be relied upon to produce complete paralysis of the motor nerve endings was about 0.00000028 gramme of curarine per gramme of body weight of male specimens of *Rana esculenta*. In about 30 minutes all general voluntary movements had ceased. Before 60 minutes all trace of reflex movement had disappeared, except in the throat muscles of respiration, which were not completely paralysed until about 2 hours after the administration of the poison. Recovery took place in the inverse order, and was usually complete in summer by 24 hours, and in winter by 2 to 3 days. A seventh part of the minimum paralysing dose caused distinct signs of motor weakness; and, after a third of the dose, the frog could not turn over when placed on its back, and did not fully regain motor power for 5 to 10 hours in summer, and for 10 to 24 hours in winter. The administration of this last dose daily for 20 days in summer and every alternate day during 40 days in winter produced only a similar motor weakness, which was least marked after the first dose or two.

On increasing the dose to eight times the minimum paralysing dose, the reflexes did not return until the 5th day, and the frog could not turn over for 2 or 3 days later. After sixteen times the minimum dose, the reflexes returned (respiratory muscles first) in 9 to 10 days, and the frog could turn over on the 14th to 16th day. In one case, where thirty-two times the minimum paralysing dose was given, the reflexes did not return until the 18th day, and the frog could not turn over until the 25th day. Generally, however, a dose thirty times greater than the minimum paralysing proved fatal, the heart ceasing to beat by the 2nd or 3rd day, and little or no urine being secreted. These observations were made at a temperature of 15° C.,

and precautions were taken to keep the skin of the paralysed frogs moist and freely exposed to air. During very warm weather, however, the smaller paralysing doses not unfrequently proved fatal, the cutaneous respiration being insufficient to support life.

Recovery from the motor paralysis was never accompanied or followed by any increased reflex excitability.

When fatal doses of curarine were administered by subcutaneous injection to rabbits, cats and dogs, the animals died in from 5 to 15 minutes from motor paralysis. When a dose slightly less than the minimum fatal of 0.00035 gramme of curarine per kilo [Boehm (20)] was administered daily by subcutaneous injection to a rabbit for 16 days, no prominent symptoms, except a varying degree of motor collapse, were observed. On many occasions the paralysis was complete except for the movement of the diaphragm. Usually by 45 minutes the motor weakness was recovered from, and the rabbit began to move about and to eat, and its health seemed in no way disturbed by the daily paralysis.

No increased reflex excitability accompanied or followed recovery, and in all respects the alkaloid produced the usual symptoms of curare poisoning in warm-blooded animals.

In order to ascertain in a curarised frog the condition of the sensory nerves, and of the central nervous system, it is usual to stop the circulation in some part of the body to protect its motor nerves from the paralysing action. Now, this end is not quite safely attained by the ligature of blood-vessels only, for, unless the dose is small, or the experiment of very short duration, the poison is apt to, and does, diffuse from the adjacent uninterrupted tissues and lymph spaces.¹

In the experiments to be described, the mode of preparing the frog employed by Bernard (1) (p. 345) was, with some modification, adopted. All the tissues at the pelvis being tied on each side to the iliac bones, the lumbar nerves being excluded, and very carefully protected from pressure.

In an intact frog the operation and tying of the tissues causes of itself great depression and irregularity of the reflexes, as tested by dilute acids. When the influence of the higher centres is removed by previous section of the cord, the operation then causes a relatively slight depression, and little or no irregularity, during an ordinary experiment of several hours duration. It is evidently not, therefore, the stoppage of the

¹ In experiments on medusæ, partially divided (Romanes (14), p. 301), diffusion seems readily to occur from one half to the other. Failure of motor power must confuse any conclusions on sensibility.

circulation in the lower extremities of the frog which may produce apparent want of power or sensibility, but the presence of the brain. It seems important to state this, because, on the one hand, the stoppage of the circulation in the legs has been erroneously held to be a sufficient cause for the reflex depression which is observed after the administration of curare; and, on the other hand, some fallacious conclusions have been come to on the action of curare on the reflex centres and sensory nerves by experimenting with intact frogs, and disregarding the possible influence of the higher centres on the reflexes.

The ordinary symptoms of curare poisoning in protected frogs seem to point strongly in the direction of general nervous paralysis. It is not always easy to contrast the experiments described by different authors, as the percentage of curarine in the various curares is unknown. No common definite system of dosage in multiples of a minimum paralysing dose of any solution of unknown strength has been adopted.

After the administration, to an intact frog, of a small dose of curarine or curare, of say twice the minimum paralysing dose (0·00002 gramme curarine in a frog weighing about 36 grammes), motor weakness of the unprotected parts appears in a short time, and by 15 minutes the last reflex twitches of the throat muscles have ceased. The symptoms are the same as with curare. The protected lower extremities continue meanwhile to maintain their normal position of flexion, and generally exhibit active reflex movements when either the poisoned or the unpoisoned skin is stimulated. It is noticeable that, although the protected parts are capable of active motion, true voluntary movements are rarely seen after the first few minutes (Kölliker (2), p. 58; Vulpian (3), p. 256; Foster (17), p. 397). After nearly half an hour the reflexes have become distinctly more and more difficult to obtain (Kölliker (2), p. 39), a circumstance hardly sufficiently recognised by Vulpian and others.

Martin-Magron and Buisson (4) (p. 526), Vulpian (3) (p. 288), and many later writers have all observed that, as the reflexes, in this early stage of the poisoning, gradually fail they become irregular; and stimulation of the poisoned skin often ceases to produce an effect, while yet stimulation of the skin of the protected part causes some reflex movement.

Martin-Magron and Buisson (4) (p. 527), however, in addition state that sometimes stimulation of the poisoned skin may not only act quite well, but may do so when a stimulation of the unpoisoned skin fails. I have repeatedly observed this last fact in frogs where the higher centres were intact. Often only the first of a series of stimulations acts, and it acts whether applied to the poisoned or unpoisoned

skin. If the poisoned skin is first stimulated, and then the unpoisoned, the impression is that the sensory nerves are paralysed. Indeed, complete irregularity of response to the stimulation of any part is, over a series of experiments, almost as marked a feature as depression, for the details of the results of the systematic stimulation of the poisoned and unpoisoned skin in one experiment are often quite contradicted by the next. The condition, except at the very beginning of an experiment, is certainly not so simple as would appear from Bernard's statement (1) (p. 353): "Toute excitation portée sur cette partie paralysée éveillera dans la partie préservée des mouvements réflexes énergiques."

From the fact that the stimulation of the unpoisoned skin usually gives the best reflexes has in part arisen the view that curare paralyses the sensory nerves, although really it is only natural that, as the protected part alone can move, and the reflexes are depressed, stimulation of its own coverings should produce a greater effect than stimulation of a distant part.

On tracing the symptoms of the poisoning further we find, with this dose, that frequently after 45 to 60 minutes ($\frac{1}{2}$ to $1\frac{1}{2}$ hour; Kölliker (2), p. 55) practically no reflex movement can be obtained on stimulating either the poisoned or the unpoisoned skin, while yet stimulation of the lumbar nerves causes vigorous movements in the protected extremities.

This fact has been generally held to indicate satisfactorily a direct reflex paralysis of the cord by the poison.

After many general, and some ninety-seven special experiments directed to the conditions of the spinal cord and sensory nerves after the administration of curarine, the following results and conclusions have been arrived at.

I. Experiments with Small Doses of Curarine of about two to five times the Minimum Paralyzing.

A. If, in an intact protected frog, the same dose of curarine be administered as in B, and about 45 to 60 minutes after poisoning, when the reflexes are very irregular and depressed, or have disappeared to stimulation of either the poisoned or the unpoisoned skin, *the spinal cord be successfully divided below the medulla*, the condition of reflex depression and irregularity and apparent sensory or spinal paralysis quickly changes, and active movements of the protected parts regularly follow every stimulation of either the poisoned or the unpoisoned skin.

Example.—*Exp. No. 57. Oct. 1887. Temp. 15° C.* Preparation of lower extremities as usual. Injection of 0·00003 gramme curarine—equal to twice the minimum paralyzing dose—in 0·3 c.c. water.

Minutes after
poisoning.

- 7 Spontaneous jerk of legs. No further spontaneous movements throughout the experiment.
- 15 Complete motor paralysis of all parts except the lower extremities.
- 18 Reflexes to dilute sulphuric acid—3 per cent.
 Left foot withdrawn in 20 sec.
 Right " " 1 "
- 28 Left foot not withdrawn in 70 "
 Right " " 70 "
- 38 Left " " 70 "
 Right " " 70 "
- Meanwhile the reflexes to pinching either the poisoned or unpoisoned skin continue good and fairly regular.
- 45 Reflexes to pinching becoming rather difficult to obtain; pinching the protected feet gives the best reflex.
- 50 Reflexes further impaired and very irregular. Sometimes pinching the poisoned skin acts when the unpoisoned skin fails, and sometimes both act, or twenty successive stimulations to all parts cause no movement. When systematically applied at intervals, the *first* stimulation, as a rule, causes a reflex, irrespective of the skin being poisoned or not, while second or third stimulations applied at the same time fail. There is much irregularity, however.
- 60 Strong acetic acid applied twice to the poisoned or unpoisoned skin without any distinct reflex movement following. Pinching usually entirely fails to act. The lower extremities remain flexed.
- 65 The spinal cord now carefully exposed above the level of the brachial nerves. During the cutting of the tissues and bones not the least sign of life occurred in this experiment, as if the sensory nerves or nerve centres were paralysed. Complete section of the cord, with very sharp, small, thin-bladed knife to prevent dragging or bruising. Very slight hæmorrhage.
 The lower extremities vigorously extended on making the incision.
- 68 Complete change in the reflexes. Every pinch of either the poisoned or unpoisoned skin immediately causes a reflex movement; and the reflexes to the dilute acid have reappeared.
 Right foot withdrawn in 22 sec.
 Left " " 11 "
 Right " " 10 "
 Left " " 7 "
- 95 The same results, but the movements becoming very feeble.

In similar experiments with vigorous frogs, where the spinal cord was divided successfully during this stage of reflex depression, results of a like kind were always obtained. When the poisoned anterior extremities were allowed from time to time to dip into the dilute acid, after section of the spinal cord, reflex movements regularly followed in the unpoisoned posterior extremities, although, previous to the division, no form of stimulation produced any effect. In one case, notwithstanding the mutilation and the depression caused by the successive severe operations, the spinal cord retained its vitality for 7 hours after section, and stimulation of either the poisoned or the unpoisoned skin caused reflex movements.

These experiments occasionally failed, chiefly from (1) imperfect ligature of the vessels and tissues at the lower part of the abdomen; (2) pressure of the ligatures, or compressed tissues, or displaced organs (kidneys), against the trunks of the lumbar nerves; (3) rapid paralysis of the cord after section, even when every care taken in the operation. This seemed especially to occur in warm weather.

The following sets of experiments seemed to remove all chance of error.

B. If the *spinal cord in the frog be successfully divided below the medulla on the day previous to the experiment*, and the same relative dose of curarine be administered as in A, the early irregularity and depression or disappearance of the reflexes, which is usually such a marked feature of curare poisoning in experiments on the *intact protected animal*, does not occur at all, nor can any apparent difference between the sensibility of the poisoned and of the unpoisoned skin be observed.

Example.—*Exp. No. 44. Sept. 1887. Temp. 17° C.*

The spinal cord divided on the day previous to the experiment, and the lower extremities protected in the usual manner one hour before poisoning.

Minutes before poisoning.	Reflexes to .3 per cent. Sulphuric Acid.		
21	Both feet withdrawn in	2-4	Beats of Metronome (exact equivalent in seconds omitted to be obtained).
18	"	2-4	
12	"	2-4	
6	"	2-4	
0	"	2-4	

Administration of same relative dose of curarine as in the experiments on intact frogs.

Minutes after poisoning.	Reflexes to '3 per cent. Sulphuric Acid.		
2	Both feet withdrawn in 2-4 beats.		
8	"	"	2-4 "
14	"	"	2-4 "
23	"	"	2-4 "
33	"	"	2-4 "
43	"	"	2-4 "
53	"	"	3-4 "
63	"	"	3-4 "
95	"	"	3-4 "
2 hours	"	"	4 "

During the whole period, pinching either the poisoned or the unpoisoned skin instantly caused a reflex movement in the protected lower extremities.

These results were repeatedly confirmed, and made it evident that some other explanation must be given of the symptoms produced by small doses in *intact frogs* than an early direct depressing action on the cord or sensory nerves. The fact that the sensory nerves are not paralysed receives confirmation from other experiments, C.

C. If the spinal cord in a frog be successfully divided below the medulla, and *an enormous dose of curarine be injected into one extremity*, which is so isolated from the body that all transfusion of fluids is prevented, but nervous connection is retained, yet, *delicate stimulation of the skin of this paralysed and greatly over-poisoned part causes, during many hours, an active reflex movement in the rest of the body.*

Example.—*Exp. No. 70. Decem. 1887. Temp. 15° C.*

Spinal cord divided just above the brachial nerves on 10th December, and on the 13th December the lower extremities prepared in the usual manner, an extra ligature at the pelvis preventing diffusion between the isolated extremities. Subcutaneous injection of 0·0015 gramme curarine dissolved in '25 c.c. water into the right leg. *A dose sufficient to completely paralyse ninety frogs of the same weight as the one experimented upon was thus introduced into a part of one extremity.*

Time after
poisoning.

- $\frac{1}{2}$ hour. Complete motor paralysis of the whole right lower extremity.
- 1 hour. Faint stimulation of *any part of the skin of the paralysed extremity* causes active reflex movements in the rest of the body. When no stimulation is applied the frog remains perfectly still.
- 3 hours. The same result.
- 8 hours. The same result. The reflex movement instantly follows the stimulation of the poisoned skin.

Experiments of this kind were repeated several times, *but the saturation of the skin with overwhelming doses had no apparent influence on the sensibility.*

It is probable that the curarine, in an experiment of this kind, reached the endings of the sensory nerves in the skin, since it was administered subcutaneously and diffused to all the deep motor endings. At all events, the negative result is of some value.¹

The preceding three sets of experiments bring out clearly that the early reflex depression and irregularity in an intact protected frog, after small doses of curarine or curare, are due to an "inhibitory" influence exercised by the higher centres, and not to a paralysis of the sensory nerves or of the spinal cord.

When the cerebrum was removed, the administration of small and medium paralysing doses of curarine produced, during the following hour, practically no impairment of the reflexes; but, when in the same experiment, the optic lobes were pricked with a needle, the reflexes were at once suspended for several minutes to every form of stimulation.

Sometimes when a drop of a relatively strong solution of curarine was applied to the optic lobes, marked depression of reflexes occurred, but very soon other symptoms, presently to be described, set in.

The reflex depression caused by small doses of curarine, in addition to that caused by the operation itself in intact frogs, would seem to proceed from the cerebrum therefore.

¹ The administration of strychnine during the stage of depression in the intact frog (Martin-Magron and Buisson (4), p. 527) shows that stimulation of the previously apparently insensible parts, poisoned and unpoisoned alike, readily causes reflex tetanus of the protected part.

It has also already been noted that in protected frogs poisoned by curarine or curare, impairment or loss of volition is one of the earliest symptoms.

The depression of voluntary and reflex movement may be due to a reflex influence on the cerebrum. The frog is probably conscious, after several attempts, of its inability to make definite movements with most of its body, ceases to make ineffectual attempts with the protected part, and resists stimulation. This seems all the more likely, unless there is a common direct cerebral action, because in poisoning with paralyzing doses of Tetra-methyl, and Tetra-ethyl-ammonium and Methyl-strychnium salts, I have noticed much the same condition in intact protected frogs.

The only other explanation that occurs to me, apart from a possible direct action on the cerebrum, is a possible disturbance of the circulation in the brain. Ringer and Murrell (21) give some data of the effect on frogs of the mechanical arrest of the circulation. When the brain was present the arrest caused a strong reflex depression of the cord, since, in experiments in September (p. 73) "in entire frogs reflex action was lost on an average in 5 minutes, and in brainless frogs it persisted on an average 59 minutes."

Small doses of curarine do not paralyse the circulation; therefore, if the reflex depression in intact frogs is due to cerebral anæmia, it must arise from vasomotor spasm. I do not know of any experiments where the condition of the vasomotor centres has been determined in curarised frogs. Later experiments on the blood-pressure in rabbits will show, that, after the administration of small doses of curarine, stimulation of the skin of the paralysed animal causes intense vasomotor spasm. It is possible that the same condition exists in frogs.

Passing now to the consideration of the action of large doses of the poison, I shall try to show that its direct and indirect effects, and the obstacles which one action may throw in the way of another, have not been clearly defined, and that consequently almost all the experiments that have been made have pointed in one direction—to an erroneous view of the direct action of the poison on the spinal cord.

II. *Experiments with Large Doses of Curarine of from fifty to one hundred times the Minimum Paralyzing Dose (0.0005 to 0.001 gramme in a frog weighing 36 grammes).*

When a large dose is administered by subcutaneous injection, motor paralysis of the unprotected parts occurs in a minute or two. Purpose-like voluntary movements quickly disappear in the protected extremities, although, at this stage of the poisoning, markedly irregular spontaneous movements occasionally occur. In the intact frog the reflexes to chemical and mechanical stimulation of the poisoned or the unpoisoned skin usually quickly become difficult to obtain, and for a time indeed are practically suppressed. This early reflex depression is not due to any direct paralyzing action of the poison on the sensory nerves or spinal cord, for, just as in the case of small and medium doses, it does not occur at all when the spinal cord is isolated from the higher centres. If, when a large dose has been given, the spinal cord be divided *during* and not *before* the experiment, it is advisable not to delay the section beyond about an hour, otherwise, for reasons which will immediately be shown, a direct weakness of the cord may have set in.

The later symptoms differ very distinctly in the following particulars from those produced by small doses:—

1. The reflex depression in intact frogs continues usually for a period of from 70 to 90 minutes, and then spontaneously disappears.
2. It is followed by a period of very variable duration, during which the reflexes are either *simply improved* slightly, or, in addition, spontaneous and reflex movements of a *spasmodic character* occur.

This period of relative nervous excitement is as a rule of brief duration, and the spasmodic symptoms, although unmistakable in character, are, when present, slight and easily exhausted.

Marked depression of reflex excitability rapidly follows, and, in from 3 to 5 hours usually, passes into *total paralysis* of the spinal cord. Even 20 hours, however, may elapse before reflex paralysis is complete. The *larger the dose* of curarine, and the *higher the*

temperature, the quicker the paralysis as a rule. Stimulation of the *poisoned* skin at this stage causes reflexes as long as the cord retains vitality, and the protected muscles remain contractile.

3. In a *decided minority* of cases the period of early reflex depression is followed by a *marked increase* of the nervous excitability, passing an hour or two later into complete spinal paralysis.

In about 5 per cent. of these cases *well marked tetanus* occurs.

Perhaps the precise significance of these symptoms can best be considered after one or two experiments have been described.

Exp. No. 80. Jan. 1888. Intact frog.

Time after
poisoning.

- Administration of *seventy-five times* the minimum paralyzing dose.
- | | |
|--------|---|
| 2 min. | Complete motor paralysis of unprotected parts. |
| 15 " | Disappearance of reflexes to dilute acid. |
| 30 " | Progressive impairment of reflexes to pinching. |
| 62 " | No voluntary movement during the last 47 minutes.
<i>Spontaneous</i> movements now occur from time to time. These movements are <i>inco-ordinate</i> , and consist of a jerky extension of the lower extremities, or a slow sprawling movement, or a slow, spasmodic-like extension, the web of the toes being outstretched. |
| 80 " | Reflexes to pinching are <i>much more easily</i> obtained now. |
| 100 " | A slight touch on <i>either the poisoned or unpoisoned</i> skin causes a quick, jerky extension of the lower extremities. When the stimulation is slight crossed reflexes are well seen. |
| 3 hrs. | Feet withdrawn from the dilute acid in 6 <i>seconds</i> . <i>Moderate tetanus</i> can be induced from time to time on pinching <i>any part</i> of the skin or tapping the body. |
| 4 " | Spontaneous movements ceased, and reflexes no longer obtained on stimulating the skin, the upper end of a divided sciatic nerve, or the upper end of the cord. Stimulation of the lower end of the divided sciatic nerve, or the lumbar nerves of the other side, causes active movement of the lower extremities. |

Exp. No. 81. Jan. 1888. Intact frog. Temp. 16° C.

Administration of seventy times the minimum paralyzing dose.

Time after poisoning.	
25 min.	Reflexes distinctly depressed.
80 "	Slight improvement of reflexes.
2 hrs.	Occasional slight spontaneous movements.
6 "	Reflexes distinct, but feeble and easily exhausted.
16 "	Pinching the poisoned skin of back and anterior extremities causes <i>feeble</i> contractions in the upper thigh muscle, the rest of the extremity having become dry and rigid. The heart beat not to be observed on the thorax.
26 "	Condition unchanged, but, when next observed, paralysis was complete, the cord having retained vitality for a much longer time than usual.

Exp. No. 82. Jan. 1888. Frog with divided cord. Temp. 18° C.

Spinal cord successfully divided on the day previous to the experiment.

Minutes before poisoning.	
10	Feet withdrawn from .3 per cent. sulphuric acid in 4 to 5 seconds.
0	Feet withdrawn from .3 per cent. sulphuric acid in 4 to 5 seconds.
	On pinching the feet the reflex is very active.
Time after poisoning.	
	Injection of 1 c.c. solution containing 0.001 gramme curarine. Frog weighs 88 grammes—about <i>forty times</i> the minimum paralyzing dose.
5 min.	Complete motor paralysis of the unprotected parts.
13 "	Frequent slight spontaneous movements in the lower extremities.
15 "	Reflex to dilute acid in 5 seconds—to pinching immediate.
18 "	Both lower extremities frequently forcibly extended and flexed. While in the position of flexion and extension, faint, irregular movements of muscles.
30 "	Frequent spontaneous movements; no diminution of reflexes as in the intact frog.
40 "	<i>Distinct tetanus</i> following stimulation. The lower extremities often quite rigid for 5 to 10 seconds. <i>This condition, with intervals of rest, continued for 20 minutes.</i>
60 "	Spontaneous movements less frequent, and the tetanus when induced is brief, and the necessary intervals of rest longer.
	To dilute acid, $\left\{ \begin{array}{l} \text{Right foot in 15 sec.} \\ \text{Left " " 9 " } \end{array} \right\}$ But difficult to observe the exact time of true reflex.
80 "	Reflexes much weaker, and tetanic movements difficult to obtain.
95 "	A brief tetanic spasm on pressing the foot.
2 hrs.	No further reflex. Direct stimulation of the lumbar

nerves causes active movements in the lower extremities.

Many of the experiments were without decided evidence of tetanic action, but showed some suspicious symptoms—partly paralytic and partly convulsant.

Exp. 59. Oct. 1887. Divided cord. Temp. 15° C.

Time after poisoning.	Cord divided on previous day.
	Injection of 0·00025 gramme curarine in 0·25 c.c. water = thirty times the paralyzing dose.
7 min.	Paralysis complete in unprotected parts.
32 „	Reflexes have continued good—no exaggeration of reflexes.
49 „	After the reflex movement has taken place, some twitchings shown in the legs, and occasionally spontaneous jerks occur.
59 „	Reflexes very acute (but no tetanus) on touching any part.
69 „	Reflexes slowly becoming less acute.
79 „	Reflexes distinctly feeble.
109 „	Only a faint reflex movement obtained.
2 hrs.	Complete paralysis of the cord.

After many such experiments it became absolutely certain that the subcutaneous administration of relatively large doses (0·0005 to 0·001 gramme) of curarine caused in intact frogs the disappearance of the primary reflex depression, and produced in a proportion of all the cases symptoms generally understood to signify “stimulation” of the spinal cord. I especially repeated the experiments over and over again as the result was quite contrary to the general belief.

Without a pure curarine such a question could never be settled, for, in experiments with a doubtful mixture like curare (assuming meanwhile that the same results are obtained), there must always have remained with it an uncertainty as to *what caused the tetanus, and what the paralysis.*

Now, while the “stimulation” of the spinal centres shows itself, on the one hand, in the early spontaneous disappearance of the reflex depression, and on the other hand in the appearance more or less of reflex spasm, it remains to be explained why in the first place *total paralysis* of the spinal cord occurs in the *majority of cases* in a few hours, and why, in the second place, if stimulation of the cord is a true action of the larger doses of

the poison, *the appearance of reflex tetanus after subcutaneous administration is inconstant, and occurs only in a relatively small proportion of cases.*

The explanation of these important negative facts is, I think, undoubtedly to be found in the great change produced by large doses of the poison (·001 gramme) *in the circulation.*

It is known that large doses of curare impair the diastolic filling of the heart (Vulpian (3), p. 354), which may, after several hours (Von Bezold (7), p. 168, &c.), cease to beat. In my own experiments where large doses of curarine were given, and the thorax not opened, the heart continued to beat for a good many hours, or even for a day or two.

If in an ordinary experiment where a small dose of curarine has been administered the heart be exposed and watched, little immediate change occurs in its condition, if the frog during the observations is under the same conditions of temperature as before the experiment.

After a time the blood becomes dark owing to the general muscular paralysis having stopped the respiration by the lungs; and, especially in warm weather, a distinct slowing of the heart's action sets in. This cannot be attributed to any direct action of curarine, for simple artificial stoppage of respiration by the lungs slows the heart in summer frogs.

When large doses of curarine, however, are administered, there may be a quickening of the heart's action for a minute or two, soon followed by a marked slowing. The inhibitory action of the vagus is suspended. But what is most noticeable is a distinct diminution *in the volume of the heart.* The diastolic filling becomes very imperfect, although the rate is not at first affected much. A change in this direction begins several minutes after the poison has begun to act, and in a variable time which it is difficult to estimate correctly, but often within 30 minutes, it is practically an empty ventricle that for the time being continues its regular contractions. It will be shown that in warm-blooded animals large doses of curarine greatly lower the blood-pressure, just as curare does. Since in the frog the heart itself continues to act well, though more or less empty, it is evident that the blood-vessels are in some way paralysed. If the abdominal viscera be examined, it will be found that the

veins are greatly distended with dark coloured blood. If the spinal cord be divided, there is practically no hæmorrhage.

It is evident that the supply of oxygen is cut off, for not only is the pulmonary respiration of necessity stopped, but the cutaneous respiration is also practically at an end, for the blood is no longer actively circulating throughout the skin of the paralysed animal. This is confirmed by the fact that in deeply curarised frogs the gas analysis (Valentin (22), p. 99) shows a marked sinking of the oxygen absorbed and carbonic acid given off, and the muscles have no longer a red colour, whereas in frogs paralysed by small doses of curare, and where consequently the circulation in the skin is not so much influenced, the gas analysis shows that the oxygen absorbed is not diminished.

Under the conditions of the circulation therefore brought about by a large dose of curarine, the quantity of oxygenated blood which can reach the central nervous system must usually be very small.

It has often been shown that when the aorta is compressed, or the heart paralysed, or the frog surrounded with an irrespirable gas, &c., or, in other words, when the blood can obtain oxygen but cannot circulate, or circulates but cannot obtain oxygen, the central nervous system becomes after a time paralysed. In control experiments I generally found that the paralysis of the cord was *complete* in about 45 minutes in very hot weather, and in from 1½ to 3 hours at lower temperatures in winter.

Now curarine, in large doses, produces, in a short time, a condition of the circulation *similar to that which would be caused by the ligature of all the veins entering the heart*. In experiments where the spinal cord has been previously divided the circulatory paralysis is, if possible, accentuated by the vasomotor centres being cut off.

It is certain, therefore, that the alkaloid is not only imperfectly circulated, but that it must, by causing this great dilatation of the blood-vessels, indirectly weaken and paralyse the central nervous system; and this secondary paralysis must occur, no matter what the direct action may be of that part of the dose which may reach the brain and cord.

Since marked impairment of the circulation sets in with the subcutaneous injection of such a large dose of curarine as 0·001

gramme, it is impossible to say how much of it is ever carried to the spinal cord.¹

Assuming for the moment that the direct action of large doses of curarine on the cord is a "*stimulating*" one, then the *infrequency of tetanus* after subcutaneous injection shows that the part of the dose which does reach the cord is generally either insufficient to produce tetanus, or it reaches too late to overcome the weakness produced by the want of oxygenated blood.

It is known that the cardiac contractions may continue in the frog for a considerable time without blood, and it would therefore be a mistake to assume at the beginning of pronounced curare poisoning that, because the *heart movements* were to be observed on the thoracic wall, *the circulation* was being efficiently maintained.

Later experiments show that the infrequency of tetanus and the spinal paralysis can only be explained by the failure of the circulation.

We may now proceed to the further statement that, when the inevitable fallacies which attend the subcutaneous administration are avoided, by applying the poison directly to the cord, and by injecting a solution of it into the aorta, *the symptoms are constant and quite unmistakable, and show that the true primary action of at least the larger doses of curarine on the spinal cord is that of a convulsant poison allied to strychnine.*

A. *The Local Application of Solutions to the Spinal Cord.*

Before applying a solution of curarine it is necessary, in an unprotected frog, to suspend the circulation by ligature of the aorta or heart, to prevent the poison being conveyed to the muscles. Experiments are most completely satisfactory in winter, as the cord retains its vitality for from 1½ to 3 hours after the circulation is stopped.

Exp. No. 86. *Jan.* 1888. *Temp.* 12° C.

Brain destroyed to prevent voluntary movements. Heart ligatured.

¹ Vulpian (3) (p. 359) shows that in curarised frogs the action of Digitalin, Strophanthin, Upas Antiar, Jaborandi and Muscarin is much less in degree, and the symptoms much later in appearing, than when similar doses are given to non-curarised frogs, and that this indicates delayed absorption.

Minutes after poisoning.

- 15 Whole cord exposed without injury. No movements when undisturbed.
- 30 During the last 30 minutes 30 drops of a solution (1 in 10,000) allowed to trickle over the spinal membranes, which are mostly intact. Most of the solution necessarily escaped. Not the faintest movement has occurred.
- 50 During the last 15 minutes 15 drops of a solution (1 in 1000) of curarine, applied as before.
- 51 *Violent tetanic spasm* of the whole body, lasting 15 seconds (about), on accidentally shaking the table.
- 52 *Tetanus follows every stimulation.* Often successive shocks occur, lasting about 5 seconds each.
- 65 *Frequent spontaneous tetanic shocks during the last 10 minutes*, some of them lasting almost continuously for a minute.
- 75 Frequent twitching of individual muscles.
- 95 Violent tetanus, lasting 20 seconds, on pinching the foot.
- 2 hrs. Tetanus very brief, and relatively feeble.
- 2½ Feeble reflexes only.
- 3 Paralysis of cord, having remained active without blood for about 3 hours at this temperature.

Exp. 87. Jan. 1888. Temp. 13° C.

Minutes before poisoning.

- 35 Brain destroyed, heart ligatured, and cord fully exposed.
- 15 Frog has been left undisturbed for 20 minutes to see if any signs of excitement from injury, exposure, or any imaginary combination of circumstances could act. Not the faintest movement has occurred. On pinching the foot the reflex is simple, and not at all strong.

Minutes after poisoning.

- Application of 2 drops of solution, containing 0.0005 gramme curarine. The membranes lining the spinal canal were in great part unbroken, and the cavity filled with lymph and some blood, so that the curarine did not come into quite immediate contact with the cord.
- 16 *Violent tetanic convulsion*, lasting for 16 seconds (about), and the faintest touch or vibration renews the spasm.
- 23 *Repeated spontaneous tetanic spasms.* These often begin slowly, the extremities being moved about in various directions, according to the muscles most in action, and, finally, all parts become affected, and a *most intense tetanus* sets in, lasting for a minute perhaps.
- Reflex tetanus immediately follows a stimulation.
- 2½ hrs. Spontaneous jerks, &c., have ceased. Reflex tetanus very feeble and brief.

When the spinal cord is carefully and completely divided into

two parts before applying the solution, it is found that tetanus occurs in the muscles supplied from both parts, showing that the symptoms are directly due to an action on the cord. When the dose is very large—several milligrammes—tetanus of the most violent kind sets in after a few minutes, and the bloodless cord is sooner exhausted; or it may possibly be that the poison finally exercises some direct paralysing action in addition. Such experiments prove that the local application of, say, half a milligramme or so of curarine produces marked and true tetanic symptoms; and, when a healthy frog is used, and the cord is not seriously injured in the preparation, and the motor nerve ends are thoroughly protected, *the appearance of tetanus is invariable.*

Since the subcutaneous injection of a solution of curare or curarine in a warm-blooded animal seems absolutely non-irritating, and since the solutions employed were very weak (average 1 in 1000), neutral in reaction, and free from impurities of any kind, it is quite improbable that a tetanus of the nature described could result from any local irritating action, as that term is ordinarily understood. The symptoms are the same in kind as those which, under the same circumstances, follow the application of strychnine, while the dose of curarine is larger and the symptoms of shorter duration. It is impossible, however, to experiment with large doses of curarine under the same conditions as with strychnine, and they cannot be fully contrasted therefore. Even if the heart be not artificially arrested, the dose of curarine which tetanises must, on absorption, greatly weaken or paralyse the circulation.

B. *Injection into Blood-Vessels.*

A satisfactory demonstration of the tetanising action of curarine is obtained when it is conveyed to the cord through the blood capillaries.

Very speedy results were always obtained when the experiment was made in the following manner:—Ligature of the common abdominal aorta *above* the origin of the large common intestinal artery (coeliaco-mesenteric), ligature of one aorta at its origin, and one pulmo-cutaneous trunk. On making the injection by means of a cannula in the other aorta close to the heart, the only important vessels through which the solution can pass are

the carotid and occipito-vertebral arteries of one side, that is to say, the vessels which supply the central nervous system. If the sub-clavian artery, or the arm on the same side, be also ligatured, the great part of the solution passes directly to the brain and cord. The experiments are most successful when the temperature is not high, as the cord does not lose its vitality so quickly when deprived of blood.

Exp. No. 90. Jan. 1888. Temp. 13° C.

Minutes after
poisoning.

- | | |
|----|--|
| | Preparation as described, the cord having been divided to prevent voluntary movements, and the brain destroyed. |
| 1 | Slow injection of .8 a.c. solution, containing 0.0008 gramme curarine, into the left aorta. Almost <i>immediate appearance of jerks and spasms</i> , which continued nearly without interruption for 50 minutes. |
| 7 | <i>Severe spontaneous tetanic convulsions</i> , followed by constant spasm of individual muscles and groups of muscles, the extremities being jerked about in all directions. |
| 15 | The tetanic spasms still continuing with extreme violence, and when these abate every muscular fibre is in a state of constant twitching. |
| 25 | The violence of the spasms abating somewhat. |
| 55 | Gradual cessation of spasms. Only feeble movements on stimulation. |

The same results were obtained in every experiment. When several milligrammes were injected, the tetanus was almost *instantaneous* and *exceedingly violent*. The *instant appearance* of tetanus here shows that the late and inconstant appearance of spasmodic symptoms *after the subcutaneous injection* of large doses is not due to any true delayed action on the cord, but to the circulatory difficulties.

Kölliker (2) and Bernard (1) made special experiments with curare *without observing tetanus*. In Kölliker's (p. 39) experiments the curare was administered subcutaneously, and when the reflexes had disappeared the cord was divided and strychnine immediately applied. The first part of the experiment was exposed to the fallacy which attends subcutaneous injection; the strength of the dose is unknown; and the immediate use of strychnine after the division of the cord prevented any further observations.

In Bernard's experiment (p. 329) the curare was *applied locally* to a part of the cord. The experiment has this value that the cord was not depressed, but for several reasons it would be valueless as a proof that curare is not a tetanising poison. In the first place the *strength*

of the dose is unknown. The time the frog was under observation is not stated; and we do not know whether *only one*, or more than one experiment was tried. Indeed, the experiment is so briefly dismissed that it is evident that Bernard never seriously experimented in this direction.

So far as I have read, no other special experiments have been made, and there is therefore no further opposing evidence of an *experimental* kind to consider.

III. *Experiments with Curare.*

If curarine is a tetanising poison, it becomes very probable that *every genuine motor paralysing specimen of crude curare* has this action. As it seemed important to substantiate this, I carried out a series of observations on pithed frogs in the Pharmacological Laboratory of Edinburgh University during the winter 1888-89.

The following specimens of curare were examined:—

1. Poisoned darts of the Macusi tribe of Indians in British Guiana. From Sir Andrew Halliday, Army Medical Service, presented to Professor Christison in 1839.
2. Poisoned arrows from same source.
3. Poisoned darts from British Guiana, obtained by Professor Simpson in 1848.
4. Poisoned arrows from same source.
5. Urari poison in gourd from same source.
6. Urari poison in gourd from Dr Ewan Cameron, Berbice, in 1849.
7. Curare from "Agassiz gourd, Brazil," presented to Professor T. R. Fraser in 1870 by Dr Weir Mitchell.
8. Curare from "Pot from Paya, from Agassiz," from same source.
9. Curare from "Pot from Para," from same source.
10. Curare from "Pot from Academy of Natural Sciences, now in possession of Dr Hammond," from same source.
11. Curare (source unknown) purchased from Messrs Hopkin & Williams. London, 1888-89.
12. Curarine from same source.
13. Curare (source unknown) purchased from E. Merck, Darmstadt, 1888-89.
14. Curarine (curin frei) from same source.
15. "Wourali poison of Guiana, presented to Dr Traill from Dr Schomburgk in 1842."

The first six specimens and the last are in the *Materia Medica* Museum of the University of Edinburgh, and for these and the next four specimens I am indebted to Professor Fraser.

The different specimens were standardized by making solutions in distilled water, filtering, and approximately determining the activity of the filtrate on two or three frogs. Taking the quantity which was found to be the minimum paralysing dose to contain about 0·00000028 gramme of curarine per gramme weight of frog, the filtrates were evaporated at a low temperature until in each case about ·5 c.c. would contain roughly 0·001 gramme curarine.

The details of the experiments were the same as in the case of similar experiments with curarine, and it is only necessary to state the conclusion, viz., that on destroying the brain, and applying these solutions to the cord, or preferably making a direct injection into the aorta in the manner previously described, tetanus was in every case obtained readily just as with curarine. When a larger dose, corresponding probably to 2 or 3 milligrammes of curarine, was injected *instantaneous tetanus of the most marked character* set in.

These curares were selected quite at random, were of undoubted authenticity, and quite representative specimens, dating from 1837 to 1888.

It would appear, therefore, that any genuine motor paralysing curare has a *direct tetanising* action, which is readily seen when a definite dose is employed, and when, above all, the *indirect* actions of the poison are guarded against.

The cause of this tetanus we have already found in the essential active principle of the crude arrow poison—curarine—an alkaloid having, at the same time, an intensely active paralysing action on motor nerve ends.

The statement made thirty years ago that curare acted as a tetanising as well as a paralysing poison gave rise to the opinion (Husemann (24), p. 528) that experiments giving such results could not have been made with *curare*; but with some strychnine containing substance.

As no one since has observed tetanus produced by ordinary curare, it is quite disbelieved that it can have any such action.

This view has been further strengthened by the chemical examination of curare. The following investigators found no trace of strychnine or brucine:—Roulin and Boussingault (28), p. 24 (1828); Pelletier and Petroz (29), p. 213 (1829); Heintz (30), p. 452 (1847); Buchner (31), p. 528 (1861); Preyer (32), p. 1346 (1865); Sachs (33), p. 255 (1878); Boehm (20) (1886).

It is impossible that so many chemists could have failed to detect an alkaloid having the characters of strychnine, and differing in so many respects from curarine.

Curare produces tetanus through containing curarine, not strychnine.

Martius (Husemann (24), p. 526) and De Castelnau (34) (p. 14 *et seq.*) state that the Ticunas tribe employ, among others, a menispermaceous plant (*Cocculus Amazonum*, &c.) in preparing curare. This plant has been found (Couty and De Lacerda (35), p. 719) to be a convulsant poison resembling picrotoxin and nicotine. These accounts are, however, all uncertain, for as Planchon (36) (p. 105) points out, the flowers of this plant are unknown, and the species doubtful.

Admitting that the composition of curare is uncertain, the existence of any specially active body, other than a paralyzing one, must be very exceptional indeed, as numerous experiments by many observers have shown apparently that curare only paralyzes.

If it be assumed that a picrotoxin acting body may be present in the curare of a particular district, still it is very improbable that the tribes over a vast region would always add to the essential paralyzing constituent of curare a *non-essential* tetanizing one, and yet we find that all curares produce both paralysis and tetanus. When we see, further, that the *tetanizing power of curare increases and decreases in proportion to its paralyzing power*, and that the same holds good with precision in the case of curarine, we may strongly suspect that the two actions are produced by an extract from a *single bark* and by a *single active principle*.

All the evidence that has been gradually accumulated points to a strychnos bark as this *basis* of curare. Most of the plants discovered by De Castelnau (34), Humboldt and Bonpland (45), Schomburgk (30), Gubler (37), Crevaux (38), and others are fully described or discussed by Planchon (36) (p. 492 *et seq.*).

The authenticity of a number of these, as bases of curare, depends only on native or other reports, and not upon *experimental* evidence.

A number of experiments have, however, been made with extracts obtained from the barks of South American strychnos plants, and the symptoms observed have been those ordinarily attributed to curare, viz., *paralytic symptoms only, and never tetanus*.

- | | |
|---|--------------------------------|
| 1. Schomburgk (30) (p. 445), . . . | Strychnos toxifera. |
| 2. Couty et De Lacerda (35) (p. 583), . | { Strychnos triplinervia. |
| | { Strychnos Castelnææ. |
| 3. Crevaux (38) (p. 1023), . . . | { Strychnos Castelnææ. |
| | { Strychnos Crevauxii. |
| 4. Jobert (39) (p. 646), . . . | { Strychnos Castelnææ. |
| | { "Toutes ces Strychnées." |
| 5. Villiers (40) (p. 653), . . . | { Plant closely allied to, but |
| | { not Strychnos toxifera, |
| | { Planchon (36) (p. 30). |

The conclusion that the extracts from the barks of the South American strychnos plants, which form the basis of curare, act as paralyzing but not as tetanizing poisons may be given in the words of Jobert (40) (pp. 646, 647), as he seems to have examined more than

one. "J'ai expérimenté avec des extrait de toutes ces strychnées. Leur action physiologique est la même ; elles n'agissent pas comme tétanisant contrairement aux strychnées de l'Asie. Les strychnées Américaines du sud agissent d'une façon identique. Elles ne sont point tétanisantes, &c."

I can find no record of any experiments by these observers other than simple tests on a cold or warm blooded animal, showing that the extract is a poison acting after the manner of curare. There is no guarantee, therefore, that the method of experimenting would overcome the fallacies attending the investigation, or that, when paralysis was observed, anything further was specially looked for.

IV. *Experiments with Extract from Bark of Strychnos toxifera.*

Since a strychnos bark is the basis of curare, curarine must be derived from a strychnos bark, and the extract from the genuine bark must produce, contrary to the opinions just quoted, both paralysis of motor nerve ends and tetanus, since curarine does so. Fortunately, I am in a position to prove this. In the Pharmacological Laboratory at Edinburgh I received, in January 1889, through the kindness of Mr Holmes, Curator of the Pharmaceutical Society's Museum in London, a small quantity (4 grammes) of the bark of the *Strychnos toxifera* (Benth.), discovered by Schomburgk (30) in British Guiana, and described by Hooker (41) (iii. 340) and by Planchon (36) (p. 756), sufficient to enable me to carry out a number of experiments.

The bark was treated in the simplest manner. Two grammes were powdered, and an infusion made with cold distilled water. After several hours this was filtered, and a yellowish, bitter fluid obtained, having all the appearance of a moderately strong solution of curarine.

Experiments were then made on pithed frogs.

On determining the poisonous activity of the filtrate, it was found that about $\frac{1}{1000}$ th caused in a frog (*Rana temporaria*), weighing 26.3 grammes, distinct weakness in 15, and complete reflex paralysis in 45, minutes. Larger doses caused paralysis in a minute or two, and this was found, when a part was protected, to be due to an action on the endings of the motor nerves.

As the motor paralysing dose of curarine for an intact frog (*Rana esculenta*) of this weight is 0.00000736 gramme, the 2 grammes of bark would roughly contain—to judge by the physiological test—about 7 per cent. of curarine.

A frog was then prepared by destroying the brain and tying a cannula in the aorta as described in the experiments on curarine :—

- 11.35 A.M.—About $\frac{1}{100}$ th of the filtrate (probably equal to rather less than 0.0008 gramme curarine?) made up to .5 c.c. with water, and injected into left aorta.
- 11.40 A.M.—Occasionally a slight spasmodic movement, otherwise quite still.
- 11.43 A.M.—About $\frac{1}{100}$ th of the filtrate (probably equal to rather less than 0.003 gramme curarine?) made up to .5 c.c. with water, and injected as before.
- 11.45 A.M.—Marked *jerky spasmodic* movements of all the unparalysed parts, especially the legs.
- 11.50 A.M.—*Unmistakable tetanus*, the lower extremities being absolutely rigid. When a general spasm of the unparalysed muscles is not present, individual muscles and groups of muscles show frequent spasms. Reflex tetanus readily induced.

It is unnecessary to enter into any further details, as the watery extract was found to be identical in its action with curarine and curare. The quantity of bark available was much too small to allow of a satisfactory chemical examination. The other 2 grammes of bark I sent to Professor Boehm, and a few weeks later he wrote confirming the extraordinary poisonous activity of the specimen, and stating that it contained curarine to the extent of probably at least 4 to 5 per cent.¹

A *single strychnos bark* from Guiana has been found, therefore, to yield an extract containing a large percentage of an active principle which is pharmacologically, and probably chemically, identical with the pure curarine separated by Boehm from crude curare.

The bark, the crude arrow poison and the alkaloid have been shown to act in the same manner, producing paralysis by a peripheral, and tetanus by a central action.

The various conclusions in the previous part of this paper have been further substantiated, and all suppositions and misgivings as to the spinal action of crude curare being possibly due to the active principle (picrotoxin, &c.) of plants, other than the essential basis of curare, dismissed.

Most of the grounds which would discredit my conclusions have now been discussed.

The later suggestions by Gubler (37) (pp. 683) and by Bartholow (42) (p. 558), that methyl-strychnium is formed in the process of pre-

¹ The examination by Villiers (40) (p. 653) in 1885 of the bark of the *Strychnos de l'Orinoque* (Planchon), brought from the Orinoco district in 1881 by Crevaux, led also to the recognition of a body having chemical characters like curarine.

paring curare is not probable. The preparation (Humboldt (45), p. 518; Schomburgk (30), vol. v. p. 450, &c.) simply consists in the concentration of a decoction of the barks. No such body as methyl-strychnium has been found; and its chemical characters (Stahlschmidt, pp. 513-522) are not at all those of curarine (Boehm, 20). In addition, curarine has eighty-five times the paralyzing activity of methyl-strychnium sulphate.

Comparison of Curarine and Strychnine.

The researches of Martin-Magron and Buisson (4) (p. 342), Richet (50) (p. 121), and Vulpian (51) (p. 555) (3) (p. 448) have especially shown, and in quite a conclusive manner, that although small doses of strychnine salts have no particular action on the endings of motor nerves, the larger doses readily cause complete motor paralysis.

It is easy to demonstrate this in a protected frog.

On comparing the two alkaloids, strychnine and curarine, we find then that they agree very closely in the quality of their actions, but differ in the order of symptoms and in the doses required to produce them. Small doses of strychnine of 0.00001 gramme produce tetanus in small frogs, without any paralyzing action on the ends of motor nerves; while 0.00001 gramme of curarine produces complete paralysis of the ends of motor nerves, without any tetanizing action on the cord. On the other hand, 0.001 gramme or so of curarine causes immediate paralysis of the unprotected parts, and (when fallacies are avoided) violent tetanus of the protected parts; while 0.002, or better, 0.005 gramme of a strychnine salt, causes violent tetanus of the protected parts and complete paralysis of the motor nerve endings of the unprotected parts; and neither paralyzes sensory nerves.

The difference therefore between some of the main pharmacological actions of the two alkaloids remains a quantitative rather than a qualitative one.

(To be continued.)

REFERENCES.

- (1) *Leçons sur les Effets des Substances Toxiques et Médicamenteuses.* Paris, 1857, pp. 345-353.
- (2) *Virchow's Archiv*, 1856, Bd. x. s. 3.
- (3) *Leçons sur les Subst. tox. et médic.* Paris, 1882, p. 333. *Compt. Rend.*, 1854-59.

- (4) *Journal de Brown-Séquard*, t. ii. iii. iv., 1859-60, t. ii. p. 473.
- (5) *Beiträge zur Gericht. Medez. Tok., &c.*, Würzburg, 1858.
- (6) *Archiv f. Anat. u. Physiol.*, 1859, s. 59.
- (7) Do. do. 1860, s. 168, 387, 398.
- (8) Do. do. 1860, s. 477.
- (9) Do. do. 1865, s. 338.
- (10) (3) (Vulpian), *cit.* p. 288.
- (11) *Inaug. Dissert.* Dorpat., 1865.
- (12) *Zeitsch. f. Biolog.*, 1874, iv. s. 397.
- (13) *Das Amerikan. Pfeilgift.* Leipzig. 1877, s. 33.
- (14) *Philosoph. Transac.* Lond., vol. 166, 1876.
- (15) *Vorlesung. über Pharmakol.* (Bonn). Berlin, 1884, s. 135.
- (16) *Text-Book of Pharmacol.* Lond., 1887, p. 155, &c.
- (17) *Hand-Book for Laboratory.* Lond., 1873, p. 397.
- (18) *Text-Book of Physiol.* Edin., 1880, pp. 150-152.
- (19) *Cz. Hermann's Physiol.*, p. 307 ("Verhand. d. Nat. Hist. Med. vereins zu Heidelberg"), 1860, Bd. ii. 1.
- (20) "Chemische Studien über das Curare." Leipzig, 1886, s. 176—in *Beiträge zur Physiologie*—Carl Ludwig zu seinem 70 Geburtstage gewidmet von seinem Schülern.
- (21) *Journal of Physiology*, 1878-79.
- (22) *Archiv f. Exp. Pathol.*, Bd. vi., 1876.
- (23) *Handbuch. der Toxikologie*, 1862, p. 528.
- (24) *Annal. de Chimie*, xxix., 1828.
- (25) Do. do. 1829.
- (26) *Reisen in Brit. Guiana.* Schomburgk, 1847, Bd. i. and ii. s. 445.
- (27) (24). *Cz. Husemann*, p. 528.
- (28) *Compt. Rend.*, t. lx., 1865.
- (29) *Liebig's Annalen*, Bd. cxci., 1878.
- (30) *Relation d'une exped. dans les part. cents. de l'Amérique du Sud*, 1843-47, p. 17.
- (31) *Compt. Rend.*, t. lxxxix., 1879.
- (32) *Pharm. Journ.* Lond., vol. xi., 1882, p. 469, &c.
- (33) *Journ. de Thérapeut.*, No. vi., p. 682, &c., 1879.
- (34) *Compt. Rend.*, t. lxxxix., 1879.
- (35) Do. do.
- (36) *Journ. de Pharm. et Chim.* [5], xi., 1885.
- (37) *Botanical Journal*, vol. iii. p. 240.
- (38) *Text-Book of Materia Medica and Therapeut.* Lond., 1884.
- (39) *Travels to the Equatorial Regions of New Continent*, 1799-1804. Lond., 1827.
- (40) *Pogendorff's Annal.*, cviii., 1859.
- (41) *Compt. Rend.*, July 1880, t. xci.
- (42) Do. 1882, t. xciv.

VARIATION IN THE KIDNEY OF THE COMMON THORNBACK (*RAIA CLAVATA*): ITS NATURE, RANGE, AND PROBABLE SIGNIFICANCE. By G. B. HOWES, F.L.S., F.Z.S., *Assistant Professor of Zoology, Normal School of Science and Royal School of Mines, South Kensington.* (PLATE XVII.)

(Read before the Anatomical Society of Great Britain and Ireland, Feb. 26, 1890.)

WHILE the urinogenital organs of the Elasmobranch fishes have formed the subject of elaborate monographs, such as those of Balfour,¹ and Semper (10) and Bruch (2); and while, in the case of the commoner species, accurate and detailed descriptions of these organs have been from time to time published, the extraordinary variation to which the kidneys are susceptible in the Rays and Thornbacks does not appear to have been hitherto observed. My acquaintance with this variation dates from the year 1882, when there came into my hands a specimen of the Thornback (*Raia clavata*) in which the kidney of the left side was markedly abbreviated. The animal was one of a number under examination at the time, and on comparison of the several individuals there became manifest an unexpected range of variation in the kidney, and that I decided to investigate further. The opportunities arising out of an extensive laboratory practice have enabled me from time to time to supplement the notes which I originally accumulated; and, as a second specimen well-nigh identical with the first, but for the fact that it was of the opposite sex, has recently come into my possession, I have deemed it advisable to seek the publication of my results.

The kidneys of the Skates and Thornbacks lie, as is well known, wholly within the posterior half or two-thirds of the post-pericardial body-cavity; and, unlike those of a large majority of the Osteichthyes (Teleostei and Ganoidei),² they do not project into the tail. They usually terminate posteriorly

¹ *A Monograph on the Development of Elasmobranch Fishes*, London, 1878.

² Cf. especially the second Monro's classical work on *The Structure and Physiology of Fishes*, Edinburgh, 1785.

in our common British forms, on a level with the penultimate trunk vertebra, or the one in advance of it. In bulk they vary considerably, but the right one is generally the more slender. Both kidneys lie, for the most part, symmetrically placed on opposite sides of the vertebral column, and with that their inner borders are usually parallel (*cf.* fig. 2). In the male each is disposed lineally with the enormous epididymis, at least so far as its anterior portion is concerned, and the two organs present on either side a more or less close relationship, which results (as is well known [*cf.* Balfour and Semper, *op. cit.*]) from their origin in common blastemata.

The products of renal activity are carried away by ureters (*ur'*, *ur''*) which vary individually in number and mutual relationship, and open into the enlarged bases of the Wolffian ducts (*d.w'*, fig. 1*a.*), and these, in the female, become converted into a highly distensible urinary receptacle, *d.w''*.¹

Examination of fig. 1*a.* will show that the above description ill applies to the individual set of organs there delineated. The normal kidneys of an individual of the same size and sex (♀) average about 120 mm. in length (as measured along their inner borders). In the case under consideration, that of the right side measured 118 mm., and that of the left but 53. The great abbreviation of this left kidney is, however, not its only striking feature. The posterior ends of the kidneys of opposite sides are, as a rule, more or less approximated (*cf.* figs. 2 and 4), whereby the bulk of each organ divaricates from the middle line. In the aberrant individual under consideration this divarication is seen to have reached an exceptional degree. So marked a displacement as this but rarely involves the two kidneys equally; but when it does so

¹ Perusal of the current text-books shows that, so far at least as the elementary student is concerned, we are far from rid of the old confusion between this organ and the bladder of the Amniota. Jungersen has recently shown (7) that we are, after all, to regard the ovary duct of the Teleostei as homologous with the Müllerian duct of the other vertebrata. The points raised in his admirable monograph lend considerable support to a belief that the ureters of the Teleostei are Wolffian ducts; and if this be so, the urinary receptacle of the gnathostomatous fishes may justly be regarded as homologous throughout. It has been spoken of in the Teleostei as a "urocyst," by way of distinction from the allantoic bladder. I would propose to term it provisionally in the Chondrichthyes the *Wolffian bladder*.

their two bases remain approximated as usual (*cf.* figs. 4 and 5*a.*), and their point of termination posteriorly remains identical on opposite sides. In the case under chief consideration this was not so, for not only is the left kidney (*re''*, fig. 1*a.*) shortened up, but the posterior border thereof is in advance of that of its fellow of the opposite side (*re'*). I have carefully examined and measured, in all, the kidneys of eighty-six individual Thornbacks (see Table on p. 410), and of these four only showed traces of asymmetry in the point of termination posteriorly—that figured being one of their number.¹

In dealing with the question of range of individual variation, I prefer to give the results of my inquiry in tabular form; and I have endeavoured to so formulate these that they may be read at sight. It will be seen that for all individuals examined, irrespective of size and sex, the range varies between 2.0 and 7.2,—as compared with a body-cavity taken to = 10. The specimen to which I have already alluded in detail (fig. 1*a.*) was one of two in which the minimum length was realised. It was a female, while its fellow was a male, and the dwarfed kidney was in each case the left one. Perusal of the table will show that the maximum length of the kidney observed (7.2) may, like the minimum one just dealt with, be realised in both sexes. Clearly, then, the clue to the origin and significance of the variations would not appear to involve sexual characters.

Table of Measurements.

The measurements given below are, in all cases, expressed in proportion to the length of the post-pericardial body-cavity—that being taken to = 10.

The measurements of the kidney were taken along their inner borders; those of the bodies of the animals, along the dorsal middle line, from the tip of the snout to the end of the tail.

¹ In the specimen figured (Pl. XVII. fig. 1*a.*) the ureters of the right side arose in the somewhat irregular manner depicted (*ur'*); they were nine in number, and the first seven and last three respectively united to form common trunks. The five distinct tubes of the left side (*ur''*) were closely bound together in a common sheath, but they showed no trace of union. The arrangement here described is a somewhat exceptional one, and the set of ducts of opposite sides entered the Wolfian bladder, each through the mediation of a short pit or cornu with a single orifice.

	Total length of Body, in inches.	Right Kidney.	Left Kidney.
<i>Sexually Mature Individuals.</i>			
<i>Males—</i>			
i.	Ten, var. 25 to 38	5.0-5.6	5.0-6.2
ii.	Six, var. 29 to 36	5.5	5.5
	Left kidney the longer.		
iii.	One, 38	3.8	6.8
iv.	One, 36	4.4	6.2
	Right kidney the longer.		
v. ¹	Two,	7.0	5.8
vi. ¹	One,	5.5	2.0
<i>Females—</i>			
vii.	Ten, var. 27 to 38	5.0-5.5	5.0-5.8
viii.	Three, var. 30 to 37	5.5	5.5
	Left kidney the longer.		
ix. ¹	One,	4.5	5.8
x.	Two, 27	4.8	6.0
xi.	Three, var. 32 to 34	5.5	6.0
xii.	One, 38	5.6	6.4
xiii.	Four, 38	6.2	7.0
	Right kidney the longer.		
xiv.	Four, var. 29 to 37	7.2	5.3
xv. ²	One,	5.7	2.0
<i>Sexually Immature Individuals.</i>			
<i>Males—</i>			
xvi.	Six, . . . 18 to 22	4.8-5.0	4.6-5.2
	Left kidney the longer.		
xvii.	One, 19	3.8	4.7
xviii.	Three, . . . 19 to 21	5.0	5.2
xix.	One, 19	5.0	5.5
xx.	One, 20	6.2	7.0
	Right kidney the longer.		
xxi.	One, 22	4.8	3.6
xxii.	Two, 19	5.2	4.8
xxiii.	Two, 18	6.0	5.5
xxiv.	Two, 20	7.2	5.8
<i>Females—</i>			
xxv.	Six, . . . 19 to 22	4.6	4.6
xxvi.	Eight, . . . 19 to 22	5.0	5.0
	Left kidney the longer.		
xxvii.	One, 19	4.0	5.9
	Right kidney the longer.		
xxviii.	One, 19	6.2	4.2
xxix.	One, 21	6.2	4.0

¹ Length of body not ascertained.² Pl. XVII. fig. 1a.

I propose now to consider the more general aspects of this pronounced individual variation. As stated above, the measurements, in all cases, give the length of the kidney as taken along its inner border, after complete removal of its peritoneal covering. The latter is, as is well known, very thick and pigmented; and that portion of it which overlies the approximated ends of the two kidneys passes off into a densely fibrous sheet intimately related to underlying ligaments of the base of the tail. As the result of this thickening, a more or less considerable portion of the two kidneys are hidden from view in the freshly captured fish. Again, it frequently happens (especially in females [*cf.* Table]) that the two kidneys terminate anteriorly on a level with each other, and, as they lie hidden beneath the peritoneum and overlying viscera, nothing is more natural than to suppose that any two of them which so terminate are of equal length. This surmise often proves to be correct; but fig. 5a. represents a notable exception to the same. In that example (an adult ♀) the greater portion of the two kidneys were hidden from view in the manner referred to; but, upon laying them bare, the left one (*re*") was seen to be bowed outwards, and tilted as it were on edge, whereby it enclosed a deep fossa. Measurement along its inner border showed that in length it far exceeded its fellow of the opposite side. This outward displacement not unfrequently becomes very marked on the left side; but that it is not confined to the same is clear from fig. 4, in which the right kidney is seen to have undergone a similar, but less marked, distortion. I have met with two examples (both males) in which the two kidneys were affected thus; but in those, as in all where such displacement was observed, the organ of the left side was that most fully distorted.

It occasionally happens that the kidney of the one or other side (usually the right) projects back towards the base of the tail, whereby it exceeds its fellow in length posteriorly. Where this is the case, the peritoneum of the same side is correspondingly dragged backwards, and the mouth of the abdominal pore, which lies in approximation to the postero-ventral border of the corresponding kidney at the base of a deep peritoneal fossa, comes to be situated at a lower level than its fellow. None of these changes involves the peritoneum of

the middle line; that is constant in its relationships, and I have for this reason adopted as the standard of comparison, measurements taken along the middle ventral line of the post-pericardial cœlom. It may be objected that these are inadequate, in that they do not express the maximum limits of the cavity named; but experience has shown me that this objection is outweighed by the constancy of relationship of the membranes in the middle line.

I shall return to the fuller consideration of certain of the above-named facts; but I mention them here in order to guard against a palpable source of error, and to justify the mode of comparison adopted.

At first sight, and from the facts already alluded to in detail, it would appear that the two remarkable individuals with which I have mostly dealt (vi., xv.)¹ might be abnormal and pathological, and possessed of a merely atrophied renal gland. While I have met with no others in which the kidney was so markedly abbreviated, it is pertinent to point out that in those cases (iii., xvii.) in which the shortening of the kidney was most nearly the same, the organ of the right side was affected, instead of that of the left, as in the first-named examples. In one of the cases cited (xvii.) the kidneys were both clearly shortened up; and from these facts it can only be concluded that the abbreviation is not confined to the left side. The table will show that there is a tendency in the males for the left kidney to exceed the right in length; the two kidneys in this sex usually abut against the adjacent epididymes as already pointed out (*ante*, p. 408), and the lengths of the latter are usually reciprocal with those of the former. I have, however, met with rare examples, in which the kidney (of the right side) was far removed from the epididymis, there being a wide interval (of from 7 to 13 mm.) between them. I have never seen this separation on the opposite side; but these facts, taken in conjunction with the great variation in length to which the kidneys of the female are susceptible (*cf.* Table), clearly show that neither age nor sex have anything whatever to do with the processes at work. The maximum length of kidney observed was realised in an immature male (xxiv.)—the shortest in

¹ The small Roman numerals in the text refer to items in the Table on p. 410.

adults of both sexes (vi., xv.); and in relative length the left may exceed the right, or the right the left, in individuals of all ages and of either sex.

The kidneys of these animals are usually described as consisting of a number of lobes, arranged in a somewhat irregularly segmental manner (*cf.* fig. 5a). Leydig has long ago pointed out (*cf.* Semper 10, pp. 214, 215) that the left kidney is always (in *Raia batis*) subdivided into two somewhat notched (*eingekerbt*) divisions. Semper regards (*loc. cit.*) this difference between the two kidneys as only apparent, asserting that both are disposed "*gleichzeitig und in absolut identischer Weise.*" In most individuals examined by me (*Raia clavata*) this subdivision was demonstrable, the hinder third of the left kidney or thereabouts being completely independent of its anterior portion; and, in all but some few cases, the said hinder portion of the kidney was much more massive than the rest (*cf.* figs. *re.* *re.*). I have, in rare instances, observed a similar though invariably less marked hypertrophy of the base of the right kidney; this organ, like the left, may be broken up, and individual cases are easy to find which show at once that the dismemberment detected by Stannius (11) and Leydig (*loc. cit.*) is no more complete than that which may affect all parts of the kidney of either side. Individual variation is, in respect to this, very great, and it frequently happens that small lobules may be completely isolated as at * in figs. 2, 4, and 5a.

I have met with one example (an adult female [xiii.]) in which the left kidney was broken up into four distinct and (comparatively) far removed segments; but, making all allowance for individual variation, the striking constancy of that dismemberment on the left side, which Semper denied, stands out most conspicuously. That it *may* be absent I admit, as the sequel will testify; but its predominance and great regularity receive a fresh interest when it is seen (figs. 2 and 3) that a considerable interval may at the point of dismemberment occur between the leading segments of the kidney. This significant fact I have observed in ten¹ of the eighty-six specimens examined (6 ♀, 4 ♂), and Bruch has figured (2, pl. iii. fig. 1) a male of *Raia miraletus* in which a similar though less marked instance appears to have occurred. This separation would certainly appear to have resulted from a further extension of the dismemberment insisted upon by Leydig: that thus comes to form the most striking feature of the kidneys under consideration, and the cause of it has next to be sought.

If the viscera contained within the post-pericardial body-cavity in these animals be examined *in situ*, it will be seen that the cardiac chamber of the stomach lies wholly to the left

¹ In recording the measurements of these I have given the combined lengths of the actual kidney lobes, no allowance having been made for the interval named.

side, and the digestive and absorptive segments of the gut to the right, as is the case in all the Ichthyopsida and in embryos of the Amniota. The displacement of the gastric sac to the left side is intensified under the immense development of the spleen in these Batoid fishes; that organ lies side by side with the elongated and tubular pyloric sac, and the two cross the cælom at an oblique angle (represented by the line $\alpha-\beta$ in figs. 2 and 4). The point of subdivision of the substance of the left kidney, above insisted upon, is coincident with that of disposition of the pyloric sac and postero-internal moiety of the enormous spleen. The modes of disposition of the alimentary and excretory viscera are thus seen to be indubitably mutually adaptive; and two leading questions assert themselves—*a.* May not the dismemberment of the left kidney be associated with displacement under apposition with the stomach and spleen? *b.* May not the wide interruption of the kidney substance (figs. 2 and 3) be due either to divarication under displacement, or to atrophy, at the point of greatest apposition?

a. Reference has already been made (*ante*, p. 411) to individual examples in which the kidney of the left side may be (fig. 5*a*, *re''*) bowed in contour, whereby the inner border, instead of running parallel with the vertebral column, is remarkably concave. I was at first disposed to regard this modification (especially as the kidney of the opposite side may occasionally share it [*cf. ante*, p. 411, and fig. 4, *re'*]) as due to that lateral extension of the body and the pectoral fins which dominates the organization of these fishes—the kidneys appeared to be, as it were, participating in the same. The fact that the right kidney never shows any but feeble traces of such displacement, while the left may be so markedly displaced, is inexplicable on this supposition. In the animal figured (an adult ♀, fig. 5*a*.) the posterior half of the left kidney was, for the most part, upturned and deeply excavated on its inner border, coming thus to form the boundary wall of a veritable bed, upon which lay the greater portion of the spleen and pyloric gastric sac. As compared with figs. 2 and 3, the kidney had been, as it were, attenuated and displaced instead of disrupted; and it is significant to find that the posterior portion of the organ was far less distinguishable in calibre, and less conspicuously marked off, from that in front of it, than is usually the case.

That the piscine kidney may, in different genera and species, adapt itself to very variable conditions is well known to ichthyotomists, chiefly from the researches of Stannius (11, p. 264) and Hyrtl (5); and examination of any Cyprinoid will show it. Individual variation of the kind before us was, however, at first sight, hardly to be expected. I claim, concerning this, that the facts to which I have

drawn attention prove it, as concerns the left kidney of the Thornback, to be due to causes arising out of mutual accommodation with the stomach and spleen. What now of the right kidney? That, as already intimated (p. 408), is generally less robust and more ribbon-like than its fellow (*cf.* figs. *re.*' *re.*'). Its posterior extremity rarely shows marked indication of that enlargement so characteristic of the left kidney; on the contrary, its anterior moiety occasionally exhibits an increase in vertical thickness (*cf.* *re.*' *re.*' fig. 5b) as compared with the corresponding portion of its fellow. I have never observed this modification for the head of the left kidney. The line $\alpha - \beta$ of fig. 2 indicates, as has been said, the direction taken by those organs of the viscera most completely in apposition with the kidneys; and when the parts are examined *in situ*, the area of transition between the thicker and thinner portions of the right kidney is sometimes seen to be approximate to this apposition line: there is, unfortunately, no such regularity about this feature as with those characters distinctive of the posterior segment of the opposite kidney, but the facts cited suggest that the most conspicuous change in bulk to which the right kidney is susceptible may be due to the same determining cause as the displacement or disruption, with its attendant hypertrophy, in the left one. The region of apparent hypertrophy on one side may correspond with that of apparent atrophy on the other, and *vice versa* (*cf.* figs. 5b. and 1b.).¹

In two cases, one of which is represented in fig. 4, the kidney on the right side (*re.*) lay wholly behind the line referred to above ($\alpha - \beta$ of the figure); the question therefore arises whether, in these, modification might not have resulted either from atrophy of the anterior portion of the kidney, or from a shortening up of the entire organ by concentration posteriorly. To the consideration of this I shall return.

From the foregoing considerations, it may be safely concluded that the only cause to which the extraordinary individual variation undergone by the Thornback's kidneys can be satisfactorily referred is that of adaptation to the alimentary viscera (stomach and spleen).

b. When first my attention was arrested by the exceptionally abbreviated kidney represented in fig. 1a. *re.*', I regarded the case as pathological, but subsequent investigation caused me to change my mind. The results of this, embodied in my table of measurements (p. 410), clearly show that the difference in length between the two kidneys of the individual (xv.) in which this marked abbreviation occurred is, as compared with the average length of the more normal organ, but little less than that between the latter and of the longest

¹ The reflection here presents itself that, in the human subject, hypertrophy of the one kidney may be accompanied by atrophy of the other (*cf.* Handford, *Trans. Patholog. Soc. Lond.*, 1888, vol. xxxix. pp. 151, 152).

one observed (xxiv.). Therefore, the most abbreviated kidney is to be regarded as but the lowest member in a gradational series of wide range.

Comparison of figs. 1a. and 2 shows that the entire left kidney of my most abbreviated example nearly coincides in position and general relationship with the dismembered posterior segment of the less aberrant one; and, seeing what is the apparent *rationalé* of this dismemberment (*cf. ante*), the differences between the individual cases would seem to be such as would have resulted from complete atrophy, in the most modified one (fig. 1a.), of the anterior portion of the disrupted organ (*re*"). Should this be so, in view of the great constancy of the posterior segment of the left kidney, there would be reason for regarding the differences in length of that viscus as a whole as due to differences in degree of suppression of its anterior moiety.

The kidneys of the Thornback receive their arterial supply from two sets of vessels, as was shown by Hyrtl in 1858 (6. p. 29). Of these the anterior ones (*a.a.*¹, *a.a.*", figs. 1a. to 3) arise from the aorta directly, in more or less close proximity to the so-called inferior-mesenteric artery (*Mesenterica posterior* of Hyrtl);¹ while the posterior ones (*a.p.*¹ *a.p.*" of figs.) take their origins from the bases of the iliac arteries (*a.i.*). The two arteries of each side skirt the inner border of the kidney, and either unite by their branches, as Hyrtl has stated, or anastomose before branching, as shown in fig. 2. Their branches of distribution reach the kidney substance for the most part through the interspaces between its several lobes. In one of the cases in which I observed a marked interval to exist between the disrupted portions of the left kidney, the renal arteries did not anastomose (fig. 2, *re.*"); in another instance they did (fig. 3), and the anastomosis was effected posteriorly to the point of disruption. I have already shown it to be conceivable that the wide separation of the two segments of the left kidney

¹ The points of origin of these vessels are very variable. Hyrtl describes them as arising about two-fifths of an inch ("vier Linien") behind the *mesenterica-posterior*. The point of origin may, I find, or may not, be bilaterally symmetrical (*cf.* figs. 1, 2, 3); sometimes the two arteries may arise far in advance of the anterior ends of the kidneys, at others far behind these and midway between the iliac and posterior mesenteric vessels. It is exceptional to find a number of renal arteries on a side (*cf.* Jourdain, *Ann. Sci. Nat. sér. iv.*, Zoologie, t. xii. pl. 6). Parker describes (*Raja nasuta*, "Zootomy," 1884, p. 67) "numerous small renal arteries;" I have grave doubts of the existence of the extensive series represented in his fig. 20, p. 62.

may be here due to mechanical displacement (*cf. ante*, p. 414). The considerations just raised show (fig. 3) that the interval of separation may lie within the province of the anterior renal artery (*a.a.*"); neither the kidney substance nor its related vessels were in that specimen in any way exceptional; and, this being so, the disruption would appear much more likely to have arisen from atrophy under apposition with the alimentary viscera, such as that to which I have pointed (p. 414), than from purely mechanical causes unaccompanied by resorption.

It remains now to consider the facts of arterial supply in the most extreme cases of abbreviation; and I regret that this was only possible in one of the two (that of the ♀). On comparison of fig. 1*a*, which represents the case in point, with fig. 2 (supposing the relationships of the arteries to be unknown), nothing would be more reasonable than to assume that the abbreviated left kidney of the former would represent the dismembered base of that of the latter, and that the rest of the organ had atrophied, as an extension of a process already operating in the least aberrant example. In the first-named (fig. 1*a*) the blood supply of the right kidney (*re.*') was normal; that of the left (*re.*") was exceptional, and intensely interesting. In spite of the great abbreviation of the kidney of that side, the anterior renal artery (*a.a.*") arose far forwards, in advance of its predominant point of origin. The posterior artery (*a.p.*"), instead of arising from the iliac trunk, was independent, and took its origin from the aorta in advance of the latter (*a.i.*). The existence and relationships of the left anterior renal artery in this specimen are irreconcilable with the aforementioned belief in abbreviation of the kidney by simple atrophy, and to argue from them in support thereof would be almost as illogical as to deny the accepted significance of the spermatic cord, and of the course and relationships of the phrenic nerve, in mammals.

Attention has been already directed (p. 409) to the fact that the posterior border of the left kidney lay in this specimen (fig. 1*a*, *re.*") in advance of that of the right one; and, inasmuch as the vessels of the right kidney (*re.*') are normal in arrangement, it would appear (in consideration of the foregoing) that the left one

had undergone an abbreviation from behind forwards¹ as well as from before backwards, and that, as an accompaniment of the former, the posterior renal artery had lost its original connection. The alternative supposition is that, in the independence of the posterior renal artery, we may be dealing with a retention of a primitive character, but proof that this may be so is not forthcoming. These facts, then, show that the kidney, in the case in point, has most probably suffered abbreviation by concentration towards its middle, accompanied by a possible atrophy of its extremities. They prove the anterior portion of the more normal organ to be not the only one affected in the extraordinary variations herein recorded; and they raise the question how far in these variations, taken collectively, abbreviation may not be due to concentration rather than to mere atrophy, as might appear at first sight. Further research can alone settle this important detail.

I have stated (p. 415) that I was at first inclined to regard that which proves to be the maximum abbreviation (*re.* fig. 1a) of the Thornback's kidney as a pathological phenomenon, of the nature of a mere displacement such as the human kidney is well known to occasionally undergo.

Instances of the kind have been recorded, from the time of Eustachius onwards;² and it is a significant fact that in this misplaced condition the human kidney may exhibit fresh connections with either the aorta,³ or, as is here more to the point, the iliac arteries.⁴ It is particularly noteworthy that in my Thornback (fig. 1) in which abbreviation was most marked, it is precisely the last named connection which was lost; essentially speaking, therefore, that which is the abnormal condition for man is the normal one for the Thornback, and *vice versa*. The facts herein considered render it at least conceivable that the so-called misplacement of the human kidney may be no misplacement at all, but rather a reversionary phenomenon.

¹ The consideration here arises whether, in cases of inequality of backward extension, the asymmetry may not have resulted from modification by abbreviation, or atrophy, of the shorter kidney, rather than by attenuation or hypertrophy of the longer. Should this be so, it would be more correct to assert that the one kidney is the shorter than its fellow, and not the longer (*cf. ante*, p. 411).

² Quain's *Anatomy*, 9th edit., 1882, vol. i. p. 444.

³ Quain, *loc. cit.*, Eisler (3).

⁴ Quain, *loc. cit.*, *cf.* R. B. Mahon (8).

They come thus to have a significant bearing upon human morphology, and to open up therein a field for research.

Finally, Hyrtl has long ago shown (5) that in many Teleostean fishes the kidney is markedly abbreviated, and restricted to the pectoral or even post-cephalic region.¹ In rarer cases it may retire posteriorly (Gurnard, Electric Eel).² The morphological value of the kidney possessed by the first named series has been the subject of some little difference of opinion. Hyrtl regards it (5, p. 31) as his "Kopftheile," but the researches of Balfour (1) and Groszlik (4)³ leave little room for doubting that it is a derivative of the mesonephros.⁴ Comparison of the Thornbacks under my hand suggests that in the retirement of their kidney into the iliac region, we may perhaps be dealing with a phenomenon of abbreviation, the precise converse of that into the pectoro-cephalic region seen in the Teleostei; and the only fact which militates against this view,—viz. the abbreviation of the Thornback's kidney from behind forwards—may be of secondary significance.

On turning from the bony fishes to others more nearly related to the Thornbacks, I have satisfied myself that an extensive individual variation is to be met with in some (*Raia batis* *R. maculata*), but that in others (*Acanthias*, *Scyllium*)⁵ it

¹ *Pectorales pediculati*, pp. 67, 68; *Gymnodontes and Sclerodermi*, pp. 89, 90; *Cataphracti [Pterois]*, p. 53.

² Cf. Owen, *Comp. Anat.*, vol. i. p. 534.

³ Cf. also W. N. Parker, "On the Kidneys of Teleostei," *Brit. Assoc. Rep.*, 1882, p. 557.

⁴ Jungersen's observations (7) also point to the same conclusion. The only example of the kind which I have personally examined is the Fishing Frog (*Lophius piscatorius*). In a young specimen of 20 inches total length, I have observed the two kidneys to lie somewhat farther back than usual—immediately behind, that is, instead of under cover of the great clavicle, and in a position therefore indicative of a less marked forward displacement than is customarily accorded them. The viscera of this animal are, beyond doubt, affected by the reduction of the body-cavity consequent upon the great enlargement of the dorsal muscles under specialisation of the head and jaws. Ribs are suppressed, and the body-cavity is obliterated in a large portion of the region proper to the kidneys; those organs, becoming in all probability thrown forwards, come to rest in the angles of divarication of muscles which have shared in the usurping of their positions—viz., the retractors of the superior pharyngeal bones and the depressors of the clavicles.

⁵ I have refrained from tabulating my observations upon these forms, as they were far less extensive than those upon Thornbacks.

does not appear to be recognisable—at any rate so readily as in the Thornback itself. The failure to meet with it in the Selachii is not a little surprising; and, at first sight, it might be imagined that the kidney of the Thornback is in a less stereotyped condition, and thus more susceptible to change, than that of the Sharks. Features in the structure and development of the lower Batoidei, which suggest affinity with animals of more lowly organisation than, at least, the higher Sharks of to-day, are not wanting; but the general organisation of the urinogenital organs in the two sub-orders is almost fatal to a belief in the more lowly affinities of the Thornbacks. Specialisation is in them predominant; and it is extremely interesting to note that extensive individual variation of the nature herein recorded is to be met with elsewhere among highly specialised types. Parker has observed (9, p. 57) in these very animals a variability in structure of the intestinal spiral valve exceeding in extent that here recorded for the kidneys. The tarsus and larynx of certain Frogs and Toads furnish¹ examples of the kind. Our earthworms present us² with a unique case in point; and, turning from the animal to the vegetable kingdoms, genera such as *Hieracium*, *Rubus*, *Rosa*, all teach the same lesson.

That the Thornbacks have inherited a longer kidney than that which is now in them functional is certain; a large section of the same has gone over to the service of the male reproductive gland; and that which remains is seen to be variable to an unexpected degree, as the result of abbreviation more or less extensive in individual cases. These facts warrant the belief that these animals are, at the present time, undergoing a marked structural modification. It may be doubted whether, in the extent and charin of our knowledge of the great changes to which, in the past, the living organism has been subjected, we have not become abstracted and too little on the alert for evidence of change now taking place. Our British Trout, introduced into New Zealand waters, are developing serrated operculæ³—there is reason to believe that the Sirenia may be giving promise of a supernumerary

¹ *Proc. Zool. Soc.*, 1888, pp. 172-73 *et seq.*

² *Perionyx excavatus*, Beddard, *Proc. Zool. Soc.*, 1886, pp. 308 *et seq.*

³ F. Day, *Linnean Soc. Lond.* (cf. *Nature*, vol. xxxviii. p. 94, 1888).

phalanx¹—and mankind itself furnishes evidence of transient change.² I submit, with some degree of conviction, that the individual variations of the Thornback's kidneys upon which I have dwelt, point most strongly to the assumption that we are face to face with such a process of change;³ and who shall say that the abbreviations observed are not the precursors of a condition to be sooner or later seized upon, and handed down to future generations of Thornbacks as an inheritance of the past?

LIST OF AUTHORITIES CITED.

- (1) BALFOUR, F. M., "On the Nature of the Organs in Adult Teleosteans, which is usually regarded as the Head Kidney or Pro-Nephros," *Quart. Jour. Micr. Sci.*, vol. xxii., N. S., 1882, pp. 12-16.
- (2) BRUCH, E., "Études sur l'appareil de la génération chez les Sélaciens," *Thèse*, Strasbourg, 1860.
- (3) EISLER, VON, "Anomalie der Art. renalis bei Verlegerung der Niere," *Anat. Anzeiger*, 1889, pp. 465-467.
- (4) GROGLIK, S., "Zur Morphologie der Kopfniere der Fische," *Zool. Anzeiger*, 1885, pp. 605-611.
- (5) HYRTL, J., "Das uropoëtische System der Knochenfische," *Denkschrift. der Kais. Akad. der Wissensch. Wien*, Bd. ii., 1851, pp. 27-100.
- (6) HYRTL, J., "Das arterielle Gefäß-system der Rochen," *Ibid.*, Bd. xv., 1858, pp. 1-36.
- (7) JUNGBERSEN, H. F., "Beiträge zur Kenntniss der Entwicklung der Geschlechtsorgane bei den Knochenfischen," *Arbeit. a. d. Zool. Zool. Instit. Würzburg*, Bd. ix., 1890, pp. 89-219.
- (8) MAHON, R. B., "Abnormal Arrangement of the Kidney and its Vessels," *Jour. Anat. and Phys.*, vol. xxiii., 1889, pp. 339, 340.
- (9) PARKER, T. J., "On the Intestinal Spiral-Valve in the genus *Raia*," *Trans. Zool. Soc. Lond.*, vol. xi. part ii., 1880, pp. 49-61.
- (10) SEMPER, C., "Das Urogenitalsystem der Plagiostomen und seine Bedeutung für das der übrigen Wirbelthiere," *Arbeit a. d. Zool. Zool. Instit. Würzburg*, Bd. ii., 1875, pp. 195-509.
- (11) STANNIUS, H., "Anat. der Wirbelthiere," *Zweite Aufl.*, Berlin, 1854.

¹ Baur and Gadow, *Biol. Centralbl.*, Bd. vii. p. 493, 1887-88.

² Cf. especially Wiedersheim's *Bau des Menschen*, Freiburg, i. B., 1887.

³ For interesting and suggestive observations upon allied topics, see Verrill "On the Tile Fish" (*Lopholatilus*), *United States Fish. Rep.*, part x., 1882, pp. 276-283, and Herdman "On the Periwinkle" (*Littorina rudis*), *Ann. Rep. Liverpool Marine Biol. Sta.*, 1890, pp. 17-23.

EXPLANATION OF PLATE XVII.

REFERENCE LETTERS.

<i>a.a.</i> , Right anterior renal artery.	<i>cl.</i> , Remains of cloaca.
<i>a.a.</i> , Left anterior renal artery.	<i>d.w.</i> , Wolffian duct.
<i>a.c.</i> , Caudal artery.	<i>d.w.</i> , Wolffian bladder.
<i>a.g.</i> , Genital artery.	<i>d.w."</i> , Aperture of the same.
<i>a.i.</i> , Iliac artery.	<i>re.</i> , Right kidney.
<i>ao.</i> , Dorsal aorta.	<i>re."</i> , Left kidney.
<i>a.p.</i> , Pelvic artery.	<i>ur.</i> , Ureters of right side.
<i>a.p.</i> , Right posterior renal artery.	<i>ur."</i> , Ureters of left side.
<i>a.p."</i> , Left posterior renal artery.	

Fig. 1a. Thornback (*Raia clavata*). The urinary apparatus, adult ♀, with its related arteries. *Two-thirds natural size*.

Fig. 1b. Right kidney of fig. 1a. Transverse sections, across the lines $\alpha - \alpha$, $\beta - \beta$.

Fig. 2. The same, young (sexually immature) ♂. The kidneys and their related arteries, after injection with French blue. *Natural size*.

Fig. 3. The same, sexually immature ♀. Left kidney with its arteries, after injection as for fig. 2. *Natural size*.

Fig. 4. The same, adult ♀. Kidneys alone depicted. *One-half natural size*.

Fig. 5a. The same, adult ♀. Kidneys alone depicted. *One-half natural size*.

Fig. 5b. Transverse sections across the lines $\alpha - \alpha$, $\beta - \beta$, of fig. 5a.

The parts are, in all, delineated as seen while still within the body, and undisturbed.

The central dotted line of figs. 4 and 5a indicates the position of the vertebral axis.

A CASE OF MALFORMATION OF THE HEART, WITH
LARGE DEFICIENCY IN THE INTERAURICULAR
SEPTUM, PATENCY OF THE FORAMEN OVALE
AND STENOSIS OF THE AORTIC ORIFICE. By
W. S. GREENFIELD, M.D., F.R.C.P., *Professor of General
Pathology in the University of Edinburgh.*

PARTIAL deficiency of the auricular septum, other than that which is due to defective closure of the foramen ovale, is a somewhat rare malformation of the heart, although several instances have been recorded. In most of these, however, the deficiency in the septum has been towards the lower part, and has resulted from incomplete fusion of the ventricular septum with the folds which together form the auricular. In some of the recorded examples, the deficiency might almost equally well be regarded as an aperture in the upper part of the ventricular septum. In some cases the foramen ovale has also been patent to a greater or less degree.

But the conditions present in the following case, in which there was deficiency of a great part of the auricular septum in its upper and anterior portions, and, in addition, a perfectly formed, but widely patent, foramen ovale is excessively rare.

I shall, later, compare this case with some others which are on record, but it may be well first to describe it.

It is noteworthy that this defect and the associated conditions were compatible with a long and active life—in this respect agreeing with some other cases which have been observed.

A few notes of the clinical history may be given, but only such as bear upon the cardiac malformation.

R. R., a railway porter, 53 years of age, was first admitted to the Royal Infirmary under my care on December 1, 1888, complaining of shortness of breath, which was of only six weeks' duration.

The patient had always good health until recently.

Family history remarkably good; patient never had any serious illness; never rheumatic fever; has been addicted to great excess in drink. His work as a ship's steward and a railway porter has always been heavy. He never suffered from shortness of breath on exertion.

Present Illness.—About six weeks ago, one evening after work, he began to cough, and a few days later observed swelling of the face below the eyes, and, still later, swelling of the feet. The shortness of breath also became worse.

On admission he was a well-developed but somewhat emaciated man; eyelids somewhat puffy; slight œdema of ankles; very slight jaundice; marked but not great cyanosis.

Examination of the Heart.—Apex beat in fifth interspace, one inch outside mammary line; impulse, heaving, diffuse, with slight pre-systolic thrill. On percussion; upper border of heart at third rib; right, half an inch beyond right border of sternum.

Auscultation.—In mitral area sounds markedly irregular, both in force and rhythm; first sound preceded by a rough somewhat purring murmur, which is distinctly heard over apex, and conducted upwards towards the fourth costal cartilage, best heard at the latter point. First sound at apex is accompanied by a short blowing systolic murmur. This is conducted for a short distance into the left axilla. Second sound is clear and sharp, and occasionally reduplicated.

Aortic Area.—First sound replaced by a rough blowing murmur; second sound loudly accentuated.

Pulmonary Area.—A loud systolic murmur replaces the first sound; second sound is accentuated.

Pulse 80, irregular and unequal in force.

Lungs show physical signs of bronchitis and œdema at the bases.

On December 8 it was noted that the murmur was much less distinct, and was best heard in the third left interspace, and there not so well as before; heart's action had become more regular.

On December 28 he left the hospital. Cough had almost disappeared. The pulse was regular and the cyanosis had become very slight.

He was readmitted on April 15, 1889. He had remained comparatively well until a fortnight before admission, when he caught cold; the cough returned, and with it increased dyspnoea. Shortly afterwards swelling of the feet began.

On admission he was cyanotic; marked icterus; considerable œdema of legs and ankles; orthopnoea; face anxious.

Circulatory System.—Pulse 100, irregular in force and rhythm, small, poor tension. Veins at root of neck distended. Epigastric pulsation. Chest wall markedly heaved with every impulse of the heart. On palpation, impulse very diffuse and heaving. Apex in sixth interspace in anterior axillary line; no thrill. Percussion as before.

Auscultation was rendered difficult by the very irregular and tumultuous action of the heart.

In mitral area, a short presystolic and a somewhat prolonged blowing systolic murmur, second sound accentuated; in tricuspid area first sound loud and clear, second as before. In aortic and pulmonary areas sounds are not so loud; no murmur now audible in either of these areas. There is general bronchitis. Urine contains a small

quantity of albumen. Rapid improvement, as on the former occasion, was produced by strophanthus and digitalis.

Patient left the hospital, feeling quite well and strong, on May 10, 1889. The heart's action was still somewhat irregular, and the murmurs continued as before. Cheeks and nose still a little cyanosed.

He was readmitted on June 21, 1889, with similar symptoms, which had begun again a fortnight before admission. After leaving the hospital he had tried to work again, but found that the shortness of breath was getting worse, and there was a progressive development of increased dyspnoea and dropsy. On admission he was manifestly very ill. Cyanosis of the lips, cheeks, and hands very marked. Marked orthopnoea; could not lie down at all. Great anasarca of lower limbs and trunk.

Pulse 84, irregular in time and force, usually small.

Examination of heart showed chiefly increased enlargement towards the right; in other respects the condition being as before. No aortic murmur was heard on this occasion or during April. There was much oedema of the lungs. The patient appeared to be doing fairly well, when he died quite suddenly on the morning of June 26.

I was unfortunately prevented from being present at the *post-mortem* examination, and some of the points which I shall describe were overlooked. I can, therefore, only give precise information on those facts which I was able to determine some hours after the removal of the heart from the body.

Post-mortem Examination. — Pericardium contained 22 ounces of reddish serum, otherwise normal.

Heart, enormously enlarged; auricles greatly distended with dark gelatinous clot; left ventricle full of partially coagulated blood; right ventricle contains large buff-coloured gelatinous clot; heart weighed $34\frac{1}{2}$ ounces; muscular tissue of left ventricle reddish-brown and soft.

On further examination of the heart after removal the following facts were observed:—The heart is greatly enlarged, especially the right ventricle, which was much larger than the left, and of very characteristic shape; the auricles both enormously enlarged, and the appendices curiously elongated, the left coming right round to the front of the heart (see fig. 2). The right ventricle measured transversely at its greatest width 6 inches; along line of septum from apex to commencement of pulmonary artery, 5 inches; at auriculo-ventricular septum, $3\frac{1}{2}$ inches. When lying flat, the pulmonary artery at its commencement measured 2 inches in width. In removal of the heart the auricles had been laid open by an incision, which

extended from the inferior cava to the right pulmonary veins, and the exact relations of the latter could not be certainly ascertained. When opened, the two auricles were found to be separated only at the lower part, communicating freely with one another by an opening of nearly circular shape, and about $1\frac{1}{2}$ inches in diameter. (These and the following measurements were made after the heart

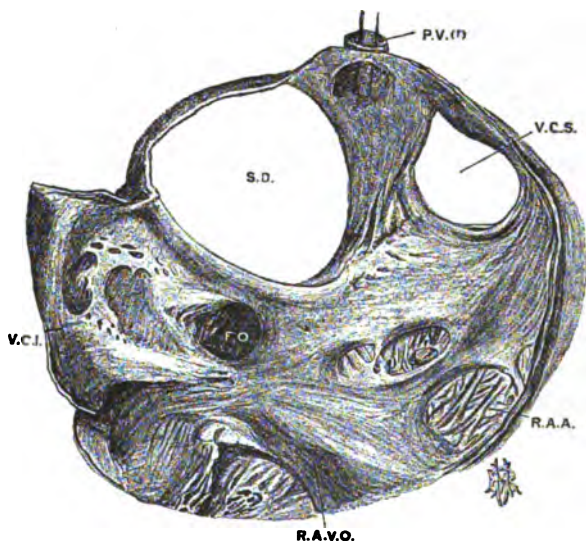


FIG. 1.—One-half the natural size.

FIG. 1.—View from the right auricle, looking towards the septum. The structures seen through the orifice (cavity of left auricle, &c.) are not drawn. One-half natural size. S.D., aperture in the auricular septum, due to deficiency in formation at the upper and anterior aspects. F.O., opening of patent foramen ovale. Between this and the deficiency in the septum is the muscular band which constitutes the most distinct part of the auricular septum, and bounds the aperture below and in front. V.C.S., opening of the vena cava superior. P.V. (?), a smaller vein which opens opposite the deficiency in the septum. (? Right superior pulmonary vein.) V.C.I., vena cava inferior, laid open. Between this and F.O. is seen the fenestrated membrane, part of which probably represents the remains of the Eustachian valve. R.A.A., opening of the right auricular appendix. R.A.V.O., situation of right auriculo-ventricular orifice.

had been for two days in weak spirit, and therefore are somewhat smaller than the actual measurements.) The upper and

a considerable part of the anterior portions of this opening were formed simply by the wall of the auricle, at the lower and more posterior part it was bounded by a septum. The upper edge of the septum was curved and thick. No ridge whatever could be discovered indicating where the septum should be attached on the upper wall of the auricles. About half an inch below the upper edge of the septum was a patent foramen ovale.

The falciform border of the lower margin of the orifice was formed of a very firm, smooth, muscular bundle, wide and pyramidal in front, and becoming narrower and sharper behind. At the anterior part, where it springs from the wall of the heart, it would be triangular in section—the right side 17 mm., the left, 12 mm., and the attached base 18 mm. Its upper free border, forming the margin of the aperture in the septum, passed insensibly on each side into the anterior wall of the united auricles. Its posterior and lower border formed the anterior wall of the patent foramen ovale.

The more posterior half of the septum was directly continuous with the anterior, but much more flattened from side to side, and somewhat sickle-shaped at its free border. Posteriorly, it gradually narrowed to the point of junction with the auricular wall, half an inch from the entrance of the inferior cava. It was continuous below on the right side with the membranous fold of the fossa ovalis; on the left, with the attachment of the mitral valve. The exact dimensions of this portion of the septum were difficult to determine; so far as could be judged, the depth of the septum, at its posterior attachment to the auricular wall, was about 60 mm.

On the aspect of the posterior half of the septum towards the right auricle is an extensive irregular cribriform membrane, only attached here and there to the muscular wall. It will be seen that it extends from the entrance of the inferior cava to the aperture of the foramen ovale. Part of it may, no doubt, represent the Eustachian valve, but from its relations this can hardly account for the whole.

The *foramen ovale* had the usual oblique direction and the usual funnel shape, but owing to the thickness of the muscular bundle under which it passed, it was of unusual length. At its

opening from the right auricle its circumference was 2 inches, at its termination on the left, $1\frac{2}{3}$ inch. Its shortest length was $\frac{1}{2}$ inch. Its orifice in the left auricle was remarkably prominent, and was situated almost close against the anterior boundary of the auricle (a not uncommon position). The blood passing through it must have impinged directly on the wall of the auricle. Coronary sinus not especially enlarged.



FIG. 2.—Three-sevenths the natural size.

FIG. 2.—Three-sevenths of natural size. View of the heart from above, to show the condition of the aorta and pulmonary artery, and the dilatation of the auricular appendices. A., aortic orifice. The anterior segment of the valves is formed by fusion of two segments, the spur between which is still visible. The aorta is dilated immediately beyond the normal orifice. P.A., pulmonary artery, enormously dilated, the valve segments normal. R.A.A., right auricular appendix. L.A.A., left auricular appendix, enormously dilated. The openings of the two left pulmonary veins are seen.

The exact relations of the right pulmonary veins could not be fully ascertained. The left pulmonary veins were normal. A large vein half an inch in diameter (fig. 1, P.V.(?)) opened into

the upper and anterior part of the right auricle. From its direction it scarcely appeared likely that it could be the upper right pulmonary vein. More probably it was a separately opening right vena azygos.

The superior and inferior cavæ were normal and not proportionally enlarged. From the position of the superior cava the blood must have passed almost equally into the left and right auricles. With the exception of great dilatation, which has already been noted, the auricles presented no other abnormality.

Left auriculo-ventricular orifice, circumference 5 inches. Mitral valve showed slight thickening; otherwise normal. The left ventricle was somewhat hypertrophied and dilated, the wall measuring at its thickest part $\frac{5}{8}$ of an inch. Aortic valves incompetent to water test, but appeared on inspection to close almost completely. The aortic valve consisted of two cusps, anterior and posterior, the anterior being formed by the fusion of two. The two cusps were of nearly equal size, the anterior, which was formed by the fusion being slightly longer than the posterior. There was very slight thickening and calcification of the spur between the fused segments, but the valves generally were not thickened. Aortic orifice greatly narrowed, about $2\frac{1}{2}$ inches. The aorta showed marked dilatation, commencing a little beyond the valves.

Right auricle greatly dilated, far more than left. Tricuspid orifice $5\frac{1}{2}$ inches; valve normal. Right ventricle enormously hypertrophied and dilated. Its wall measured $\frac{1}{4}$ to $\frac{5}{8}$ of an inch in thickness throughout a great part of its extent. Pulmonary orifice greatly dilated, $4\frac{1}{2}$ inches in circumference; pulmonary artery greatly dilated; wall of pulmonary artery greatly thickened, so that the coats were almost like those of the aorta.

Considerable difficulty was experienced in ascertaining the precise relations of the great vessels, parts of them having been lost before the malformation was observed. It was found, however, that the ductus arteriosus was completely closed, and that the origins of the great vessels from the aorta were normal. The arch of the aorta presented considerable uniform dilatation, but there was no atheroma. The aorta be-

came narrowed immediately beyond the entrance of the ductus arteriosus, a distinct ridge existing at this point, the aorta beyond it, however, being apparently of normal size. No other abnormality could be discovered.

The left pleural cavity contained about 10 ounces of sanious fluid, and the right 30 ounces; some adhesions on the outer aspect of the left lung; right lung weighed 36 ounces; left 27 ounces. The lungs showed the ordinary appearances of chronic venous congestion.

I was unable to ascertain whether there was any special dilatation of the branches of the pulmonary artery, the lungs having been thrown away before the opportunity occurred.

Spleen somewhat enlarged and congested. Liver shows chronic venous congestion, and some appearances of early cirrhosis. Kidneys congested, right kidney containing one or two infarcts.

Although there may be considerable difficulty in explaining the origin of the malformation from the point of view of development, it is not difficult to understand how, given a small deficiency in the septum during intra-uterine life, it might become gradually increased, and assume its large dimensions only after some years.

In all the recorded cases there have been present, as in this instance, narrowing of the aortic outlet and dilatation of the pulmonary. In the present case this narrowing was evidently due to the fusion of two of the aortic segments, due either to simple adhesion, or to intra-uterine endocarditis. This malformation may, indeed, be compatible with normal patency of the aortic outlet, and with perfect closure of the valve. But here it caused marked narrowing. Given this condition, the increased pressure in the left side of the heart might tend to dilate a fissure already existing in the attachment of the septum.

During intra-uterine life the existence of the aortic stenosis to a moderate degree will exert little or no influence on the general circulatory arrangements, nor will it afford any impediment to the normal formation of the rest of the septum, or to the closure of the ductus arteriosus. But the presence of another aperture in the auricular septum would prevent the increased tension in the left auricle, which is probably one of the main factors of ultimate closure of the foramen ovale, and this would therefore

be likely to remain imperfectly closed, though not dilated as in cases of pulmonary stenosis.

The conditions present in such a case are to a considerable extent the converse of those in narrowing of the pulmonic outlet. More especially if the right pulmonary veins poured their blood in part into the right auricle, and if the increased tension in the left auricle prevented the ready flow from the right towards the left, the blood would tend to accumulate in the right auricle. There will be great increase in the work to be carried on by the right side of the heart, especially the ventricle, which would in consequence become dilated and hypertrophied.

The absence of marked cyanosis might be due to the fact that the obstruction of the blood-flow being mainly on the left side, the blood would tend to pass from the left side (arterial) to the right (venous), and that therefore cyanosis would mainly occur from failure of the pulmonary circulation, rather than from direct admixture of venous with arterial blood.

Hence it will be conceivable that this malformation might exist to a considerable degree without cyanosis, and this appears to have been the case in some recorded instances. So long as the right heart sufficed to carry on its extra work no evil results would be observed.

Thus in the two cases recorded by Mr Wagstaffe (*Path. Trans.*, vol. xix. p. 96), which are almost the only exactly similar cases I can find in English literature, there was no cyanosis. In the first case, a woman 56 years of age, who died from acute pericarditis, there had been no history of cyanosis. The deficiency was in the same situation as in my case, and an inch in diameter. There was extreme mitral and aortic stenosis. The foramen ovale was completely closed.

In the second case, a child aged 6 years, there had been no cyanosis. The opening was circular, half an inch in diameter, and situated in the upper part of the auricular septum, above the foramen ovale, which was patent.

In nearly all the other cases which I can find in English literature the defect in the auricular septum has been at its lower part, the fossa ovalis or persistent foramen ovale being found above and behind the orifice.

Of such cases the following is a good example. The general

relation to narrowing of the aortic and dilatation of the pulmonic outlet is also here observed.

Dr Peacock (*Path. Trans.*, vol. xxix. p. 43) describes a case in a child aged 10 years in which the auricular septum was deficient to a large extent; in the septum of the auricles was a large rounded aperture measuring 3·4 inches (39 Paris lines, 89·75 mm.) in circumference. "This opening was bounded by thick bands of muscle, and the endocardium at its edges was somewhat thick and rough. Behind the opening and between the posterior edge and the entrance into the auricle of the descending cava, there was a small triangular space covered by a somewhat thin diaphanous membrane, which appeared to represent the foramen ovale closed by its membrane; the ductus arteriosus was completely impervious; the aortic orifice was very small, the orifice of the pulmonary artery and the trunk of the artery very large, the orifice measuring 2·93 in circumference."

I may add that, in this case, although I made the *post-mortem* examination, the heart was at Dr Peacock's request left unopened, and was not examined until it had been for some time in spirit. Only a slight degree of cyanosis had existed during life.

A somewhat similar case in a patient aged 17 is recorded by Dr Norman Moore (*Path. Trans.*, vol. xxxii. p. 40). In this case the deficiency was also at the lower part, and allowed the direct passage of blood from each auricle into both ventricles.

In nearly all the other cases which I have been able to find in English literature, where deficiencies have been present in the septum, they have been in the membranous fold of the fossa ovalis.

By far the most important contribution to the subject is found in the classical work of Rokitansky on the defects of the cardiac septa,¹ an elaborate and beautifully illustrated monograph. In this work several cases are recorded and figured, which have a more or less close resemblance to the present one.

Far more important, however, than the recorded description of the cases is the contribution to the mode of development of the septa, and the relation which the various observed defects bear to it. It is remarkable how little attention seems to have been paid by anatomists to the elaborate researches of Rokitansky and Stricker on this subject, the results of which are there recorded. Nor have I found elsewhere any mention of the observations of Lindes,² whose discoveries formed the starting-point of Rokitansky's work.

I had intended to discuss this question more fully in the pre-

¹ *Die Defecte der Scheidewände des Herzens*, von Dr Carl Freiherrn von Rokitansky, Wien, 1875.

² Lindes, *Beitrag zur Entwicklungsgeschichte des Herzens*, Dorpat, 1865.

sent paper, and to endeavour to show the confirmation afforded by the present case to the views of Rokitansky and Lindes, rather than to those of His and others, which are commonly accepted by anatomists. It would seem quite possible that the formation of the earlier fenestrated membranous septum might be overlooked, unless special modes of preparation were adopted. But it would involve too extensive a discussion for the present paper, nor have I any original observations to bring forward. I can, therefore, only commend the subject to the attention of embryologists.

PHYSICAL NOTES ON THE MOTION OF THE BLOOD
IN THE HUMAN ARTERIES. By Dr J. L. HOORWEG,
Utrecht.

1. On the 10th of November of the year 1808 Dr Thomas Young read to the Royal Society a most remarkable paper on the functions of the heart and arteries, in which he made important remarks on the velocity of the pulse-wave, the influence of friction, &c. In the course of time this paper has been almost forgotten; for, how is it otherwise to be explained that the same expression for the velocity of the pulse-wave, which can be found in the paper indicated, has been republished by Résal¹ in 1876, and by Korteweg² in 1878?

The formula—

$$c = \sqrt{g \times \frac{Ed}{2R\rho}},$$

which at present is found in many treatises of physiology,³ is nothing else than the algebraical expression of Young's rule⁴—*That the velocity of the pulse-wave is half as great as that of a body supposed to have fallen from the height of the modular column; and that this height is such that the tube would be extended without limit by its pressure.*

For, suppose the height of the modular column h , and the specific gravity of the blood ρ , then its pressure on unity square is $h\rho$, and its tangential tension on the dilated tube

$$h\rho(r + \Delta r),$$

if r the radius of the artery, and Δr its dilation.⁵

The Young's modulus of elasticity, E , being the weight by which an elastic wire of unity of area is dilated to double its

¹ Résal, *Lionville Jour.*, 1876, p. 342.

² Korteweg, "Inaug. Dissert.," Leiden, 1878.

³ Hermann, *Lehrb. der Physiologie*, 9th Aufl. p. 69.

⁴ Young's *Works*, vol. i. p. 522.

⁵ See Thomson and Tait, *Treatise*, part ii. § 576.

length, so, for an elastic tube of unity length and d thickness of shell, the radius r alters by the tangential tension calculated above, according to the proportion—

$$Ed : h\rho(\Delta r + \Delta r) = r : r; \text{ hence,}$$

$$\Delta r = \frac{r^2 h \rho}{Ed - r h \rho};$$

and the tube will be infinitely extended, when :

$$Ed = r h \rho,$$

or

$$h = \frac{Ed}{r \rho}.$$

Thus the velocity of the pulse-wave is

$$c = \frac{1}{2} \sqrt{2gh} = \sqrt{\frac{Edg}{2r\rho}}. \quad \dots \quad (1),$$

which agrees with the formula given by Résal and Korteweg.

For want of better, Young takes for h the pressure required for bursting one of the carotids of a Dog, *i.e.*, $h = 190$ feet, and, deducting from this height the 5 feet, which express the actual pressure in the arteries of a Dog, the remaining 185 feet give a velocity of at least 54 feet. Though this figure is really too high, it is very remarkable that Thomas Young calculates this velocity twenty-three years before E. H. Weber¹ discovered that in the *A. pediaea* the pulse always was felt later than in the *A. carotis*, thus twenty-three years before others had acknowledged the pulse to be a progressive motion.

If we put with Wundt² $E = 7260$ gram per cm^2 , and with Krause and others the ratio $\frac{d}{2r}$ for all arteries $\frac{1}{10}$ and g 981 cm. , and ρ 1,055, then we find by Young's rule—

$$c = \sqrt{981 \times \frac{7260}{10,55}} = 822 \text{ cm.} = 27 \text{ feet,}$$

¹ Weber, *De pulsu*, Lipsiæ, 1831.

² Wundt, *Lehrb. der Physiologie*, 1865, p. 280.

while direct measures, made by Weber and others, indicate the following figures:—

$c = 9$ mm.,	. . . . .	Weber, ¹
$c = 8$ „	. . . . .	Moens, ²
$c = 8\frac{1}{2}$ „	. . . . .	Grashey, ³

which agree with the above calculation, and so prove Young's rule.

2. In the same paper we read the following sentence:—*That a very small portion only of the resistance is created by the larger vessels: thus, at a distance of $1\frac{1}{4}$ inch only from the extreme capillary arteries, the pressure of a column of $\frac{1}{16}$ inch only is required for overcoming the whole friction, and at the 25th division, where the artery does not exceed the diameter of a human hair, the height to which the water would rise in a tube, fixed laterally with the artery, is only 2 inches less than in the immediate neighbourhood of the heart.*

So, already in 1808 Young decides the difference that in 1850 arose between Spengler and Volkmann,⁴ the former of which declares that the pressure is greater for the more remote arteries; while the second finds the pressure in the carotid 27 mm. Hg higher than in the A. metatarsi.

Young's statement was verified in 1828 by Poiseuille,⁵ and later by several experiments of Sprengel,⁶ Claude-Bernard, and Marey.⁷

Marey, mentioning the influence of gravity on the blood-pressure, says:⁸—“*La pesanteur fait plus que compenser en pareil cas la décroissance de pression du sang qui résulte des résistances à vaincre et en vertu de la quelle on trouve une tension de plus en plus faible à mesure qu'on s'éloigne du cœur.*”

So Marey, nearly in the same words as Young, teaches us

¹ Weber, *Ber. Sächs. Gesellsch.*, 1850, p. 186.

² Moens, *Die Pulscurve*, Leiden, p. 111.

³ Grashey, *Die Wellenbewegung elastischer Röhren*, Leipzig, 1881, p. 171.

⁴ Volkmann, *Hæmodynamik*, Leipzig, 1850, p. 165.

⁵ Poiseuille, *Mémoire sur la force du cœur*, Paris.

⁶ Sprengel, *Müller's Archiv*, 1854.

⁷ Marey, *La circulation du sang*, Paris, 1881.

⁸ Marey, *loc. cit.*, p. 192.

that the blood-pressure must decrease when approaching the capillaries, but that this diminution is small and insignificant.

But then we cannot be far from the reality when we suppose the blood-motion in the larger vessels to be an ordinary progressive wave-motion without friction, while the motion in the capillaries is a uniform motion, according to the law of Poiseuille,¹

$$q = \frac{1}{8} \frac{\pi a^4}{\mu l} (p_1 - p_2) = \kappa \frac{Pa^4}{l} \quad \dots \quad (2),$$

where—

q is the quantity of blood which flows through the tubes per second.

a the radius of the tube.

l its length.

μ the coefficient of viscosity.

$P = (p_1 - p_2)$ = the difference in pressure at the two ends of the tube.

This remark is important, for it permits us to calculate the blood-pressure in the larger vessels when that in the veins is neglected.

For, the capillaries carrying off exactly the same quantity of blood which is ejected in the same time by the heart, we have, when—

Q is the total quantity of blood which the heart ejects in one beat.

N the number of beats per minute.

$QN = 60P\Sigma \frac{\kappa a^4}{l}$, or, supposing—

$$60\Sigma \frac{\kappa a^4}{l} = \frac{1}{W}^2$$

$$QN = \frac{P}{W}, \text{ or}$$

$$P = QNW \quad \dots \quad (3).$$

QN is what Marey calls the debit per minute, and W is a

¹ See Lamb's *Treatise on the Motion of Fluids*, p. 224.

² Here the sign Σ extends over all the capillaries of the whole blood system.
VOL. XXIV. (N.S. VOL. IV.)

measure for the friction, and thus for that which physiologists call the *tone* of the capillaries. Hence the blood-pressure in the larger vessels depends on the heart's debit and the tone of the vessels.

When the heart begins to beat quicker the blood-pressure will rise.

When a nervous or other stimulant increases the tone W , the blood-pressure will rise also.

When the vaso-motor centre in the medulla oblongata is cut off, when the cervical spinal cord is divided, the capillaries lose their tone, W grows very small, and the blood-pressure sinks to a low level.

The same formula (3) explains how the blood divides itself in the different branches of the system. For, putting—

q_1 the quantity of blood which flows in one beat through a certain artery, and w_1 the tone of all the capillaries of that same artery, then

$$P = q_1 N w_1.$$

Likewise for another artery—

$$P = q_2 N w_2; \text{ hence—}$$

$$q_1 w_1 = q_2 w_2, \text{ or}$$

$$q_1 : q_2 = w_2 : w_1 (4).$$

The flux of blood is greater where the resistance is smaller, and because—

$$q_1 + q_2 + \&c. = Q,$$

it is clear that, when in one part of the system w increases, the quantity of blood which passes there decreases, while at the same time more blood flows through the other parts of the body.

3. The motion of the blood in the larger vessels is now, according to the observation of Young, an ordinary progressive wave-motion, with equal velocity for waves of all sorts of length and height, just like that of water in a long and narrow canal, with this distinction, that in the case of the blood the elasticity of the arterial shell acts in the same manner as gravity does in the case of the water-waves.

For these last sort of waves one has found the velocity of propagation :¹

$$c = \sqrt{g \times \frac{A}{b}},$$

where A is the area of the canal section,

b the breadth of the canal at the undisturbed level.

In the blood-motion, the dilation of the artery, Δr , has the same signification as for the water-waves in the canal the height, h , above the undisturbed level. Because the force Ed gives for every cm. of the tube length to the dimension d a dilation of d ; so, when the inner pressure is P and its tangential stress Pr , the force Pr will give to the radius r a dilation Δr , which can be found by the proportion

$$Ed : Pr = r : \Delta r; \text{ hence}$$

$$P = \frac{Ed}{r^2} \Delta r. \quad (5).$$

In the canal the accelerating force is,

$$P' = \rho h.$$

What in one case is ρ , has in the other case the value of $\frac{Ed}{r^2}$.

Thus the acceleration by gravity, g , must be changed in the acceleration by elasticity, x , according to the proportion,

$$g : x = \rho : \frac{Ed}{r^2}; \text{ hence}$$

$$x = g \times \frac{Ed}{\rho r^2}.$$

In the arteries is

$$\frac{A}{b} = \frac{\pi r^2}{2\pi r} = \frac{1}{2}r.$$

The formula $c = \sqrt{g \times \frac{A}{b}}$ is thus altered in

$$c = \sqrt{x \times \frac{1}{2}r} = \sqrt{g \times \frac{Ed}{2\rho r}},$$

which agrees with Young's rule.

¹ Lamb, *loc. cit.*, p. 177.

4. The wave-motion of water in a narrow canal has been experimentally investigated by the brothers Weber¹ in the year 1825. They have shown in an unequalled manner that, while every water particle describes a closed curve of small dimensions, the wave-motion propagates itself with great velocity to both ends of the canal. Here a *reflected* wave is formed, which progresses with unaltered velocity to the other end of the canal, where it undergoes a second reflection.

In this manner every primary wave produces a whole family of reflected waves, which *penetrate* one another without loss or hindrance, and thereby generate by *interference* at every point of the canal a motion which can be computed by simple addition of all the different motions caused at the same time by all the different waves.

Thus, *constancy* of velocity, *reflection*, *penetration*, and *interference* are the chief qualities of such a wave-motion.

5. As E. H. Weber² already has proved, the motion of the blood in the arteries may be compared with that of water that is driven rhythmically in an elastic tube, while a valve prevents it from returning to the trough out of which it is pumped. In this case we have the same wave-motion as is described in the preceding paragraph, but now there are formed no entire waves with both crests and furrows, but there arises a series of successive crests not interrupted by interjacent furrows. Each particle does not now describe a closed curve but its motion is



Fig. 1.

cycloideal, consisting in the simplest case of a series of joined half ellipses. It is just by this cycloideal motion of the particles that the *circulation* of the blood is naturally explained. See fig. 1, where abc , $a'b'c'$, $a''b''c''$, and $a'''b'''c'''$ indicate the form of the stream lines in different points of the tube. We see that in

¹ Weber, *Wellenlehre*, 1825, p. 213 *et seq.*

² E. H. Weber, *Ber. Sächs Gesells.*, 1850, p. 186.

the tube-axe itself the velocity of the particle is wanting its radial component, while, on the contrary, at the circumference of the tube fails the longitudinal component.

Such is thus also the motion of the blood in the larger vessels.

6. An elastic balloon with two valves is fixed to one end of an india-rubber tube of 9 metres length. The other end of the tube reaches in the same trough, out of which the water is driven into the tube by rhythmically squeezing the balloon. There is formed then a series of successive wave-crests just like that described in the preceding paragraph. 92 cm. from the tube's origin is placed a sphygmograph which registers the motion. A second sphygmograph is placed near to the tube's end.

When the tube is open, the first sphygmograph writes the curve fig. 2 A, and when it is closed the first sphygmograph gives fig. 2 B, and the second sphygmograph writes fig. 2 C. *a* is the *primary* wave; *b*, the *first* reflected wave; and *c*, the *second* reflected wave. The first reflected wave is in fig. 2 A a furrow, in fig. 2 B a crest. Hence the rule already given by Weber:

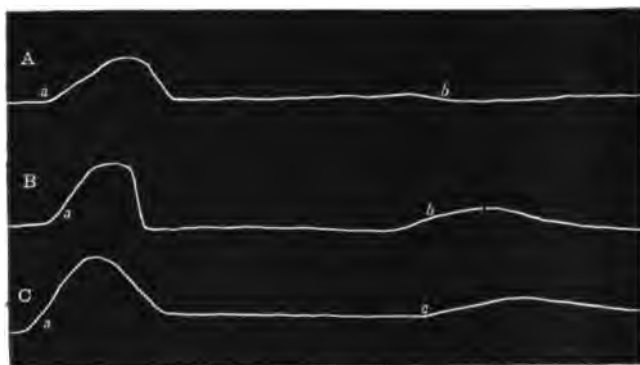


Fig. 2.

A closed tube gives a *similar* reflection (*i.e.*, a crest reflects as a crest and a furrow as a furrow), and an *open* tube gives a *dissimilar* reflection (*i.e.*, a crest reflects as a furrow and a furrow as a crest).

When the tube's end is not entirely closed, but only tightened, then it depends on the degree of narrowness whether the reflection is similar or dissimilar. Generally the widening of the tube's end is accompanied by dissimilar reflection, while similar

reflection is caused by making the end narrower. See fig. 3, where A gives the curve of the first sphygmograph when the tube's end is narrowed very much, while in B the degree of narrowness is such that reflection has wholly vanished.

In fig. 2 C we don't see the first reflected wave *b*. This is so, because fig. 2 C is registered by the second sphygmograph, placed near the end. For there the first reflected wave must necessarily fall on the primary wave, and so be covered by it.

In fig. 2 Ca the first reflected wave penetrated the primary wave; nevertheless, this same first reflected wave is found back undisturbed in fig. 2 Bb, and shortly afterwards it changed in the second reflected wave. This second reflected wave penetrates in fig. 2 Bb the first reflected wave, and yet it appears again undisturbed in fig. 2 Cc.



Fig. 3.

In the curves, fig. 2 Ca and fig. 2 Bb, two waves have interfered—in fig. 2 Ca, the primary and the first reflected wave; in fig. 2 Bb, the first and the second reflected wave. Hence their more important height.

Thus fig. 2 shows us clearly the *reflection*, *penetration*, and *interference* of the formed waves, and at the same time the distance from *a* to *b* indicates the time in which the wave has run through double the length of the tube, reckoned from the first sphygmograph to the end, *i.e.*, through a space of $(900 - 12) \times 2 = 1616$ cm.

The velocity, *v*, of the registering drum is 29 mm. per second. The distance *ab*, fig. 2, is 47.5 mm., and corresponds thus with 1.64 second in time. In 1.64 second the wave has run through a space of 1616 cm. The velocity of the wave *c* is thus 985 cm. The second sphygmograph was placed near to the tube's end; the second reflected wave, fig. 2 Cc, arrived there so much time

after the primary one, as the wave needs to run through double the whole tube's length, i.e., through 1800 cm. But the distance ac , fig. 2, is 53 mm.; hence, the difference in time, mentioned above, is $\frac{53}{29} = 1.83$ second, and the velocity of the wave $\frac{1800}{1.83} = 985$ cm., which proves the *constancy* of the velocity of propagation.

7. Generally, when a sphygmograph is placed x cm. from the beginning of an elastic tube of l cm. length, then a wave, emerging at the time T from the origin, will reach the sphygmograph—

For the first time at $\left(T + \frac{x}{c}\right)$ sec. (primary wave).

For the second time at $T + \frac{x}{c} + \frac{2(l-x)}{2}$ (1st refl. wave).

For the third time at $T + \frac{x}{c} + \frac{2(l-x)}{2} + \frac{2x}{c}$ (2nd refl. wave).

&c.

Hence, in respect to the primary wave, the reflected waves have a *retardation*, which is—

For the 1st reflected wave $\frac{2(l-x)}{c}$ second.

For the 2nd „ $\frac{2l}{c}$ „

For the 3rd „ $\frac{2(2l-x)}{c}$ „

For the 4th „ $\frac{4l}{c}$ „

&c.

So, when the velocity of the registering drum is v mm. per second, the reflected waves are registered in the pulse-curves *behind* the primary

$$\frac{2(l-x)}{c} \times v \text{ mm. for the 1st reflected wave.}$$

$$\frac{2l}{c} \times v \text{ „ „ 2nd „}$$

$$\frac{2(2l-x)}{c} \times v \text{ „ „ 3rd „}$$

$$\frac{4l}{c} \times v \text{ „ „ 4th „}$$

&c.

For the reflected waves of *even* order the retardation is the same for different points of the tube; while for *uneven* reflected waves this retardation depends also on the distance x , and therefore is *different* for different points.

For *all* reflected waves the retardation depends on the *length* of the tube. Hence, using the long tube of 9 metres' length, the reflected waves fall wholly behind the primary crest (fig. 2); but when we make use of shorter tubes of 1 or 2 metres, the reflected waves interfere with the primary one, and forms thus a complicated curve with secondary elevations, b , just as it happens to exist in the human pulse-curve (dicrotismus).



Fig. 4.

Therefore, it is an important question whether the pulse dicrotismus really is due to reflected waves, or that it depends on other circumstances.

8. In this paragraph I intend to place beyond any doubt that the pulse dicrotismus is not due to peripheric reflection.

Firstly, I observe that it is difficult by means of the rules of § 6 to predict of what sort the reflection may be.

When we think of the fact that every branch is a great deal

narrower than the chief tube, a *similar* reflection can be expected, but, considering that in every point of ramification the total area is increased, the idea of a dissimilar reflection cannot be excluded.

The following experiment may here decide:—

A rabbit's aorta was cut off near the heart, and then fixed to an india-rubber tube of the same diameter and 10 metres' length. The rabbit's whole vascular system formed thus the end of an elastic tube, in which, by the aid of an elastic balloon with valves, a saturated salt solution rhythmically was driven. The right heart was opened in order to give the solution a free passage. Near to the origin of the elastic tube a sphygmograph registered the wave-motion of the fluid. Now the rabbit was removed, and the experiment repeated with the tube alone, first closed, then open at the end. In this manner I got three series of sphygmographical curves, in the second of which the curve was changed from a furrow into a crest; but in the third no trace of reflection was observed. Hence the rabbit's vascular system is so arranged that no reflection takes place at the beginning of the capillaries.

The last four curves were obtained by squeezing the balloon in a quick rhythm, followed by a diastole of long duration. Then the pressure of the fluid rises considerably, but still no reflected wave makes its appearance.

This experiment, which I repeated also, with Professor Talma's kind assistance, on other rabbits, always gave the same results. To the same conclusion came Bernstein,¹ who, in making nearly identical experiments, could find no peripheric reflection.

Now, because the vascular system of all mammals offers us an example of very great resemblance, it is in a high degree improbable that the dicrotism in the human pulse should be caused by reflection, which fails altogether in the rabbit.

But also other reasons induce us to exclude reflection as the cause of dicrotism. For, according to the rules laid down in the preceding paragraph, the first reflected wave has a retardation, which varies with the distance x of the sphygmograph to the heart. Hence, when dicrotism is caused by the first reflected wave, or by any of the uneven order, its distance from the beginning

¹ Bernstein, *Verh. der naturw. Verein, Halle*, 4 März 1887.

of the primary wave must vary for different points of application, *i.e.*, in the pulse-curves, obtained at the same time on the same person, of the A. radialis, cruralis, and dorsalis pedis, the horizontal distance, *ps*, fig. 5, cannot be the same, the point of the A. dorsalis pedis being much more remote from the heart than that of the A. cruralis.

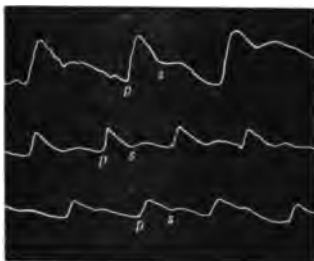


Fig. 5.

This, however, is not the case, as we see in fig. 5, where the *under* series of curves is taken from the A. radialis, the *second* from the A. dorsalis pedis, and the *upper* series from the A. cruralis of the same person.

In all three the distance *ps* is exactly 4 mm. Likewise, in fig. 6, where we find two series of sphygmographical curves registered at the same time—the *upper* series taken from the A. radialis, the *under* from the A. carotis of the same person. In both the horizontal distance *ps* is 8 mm.

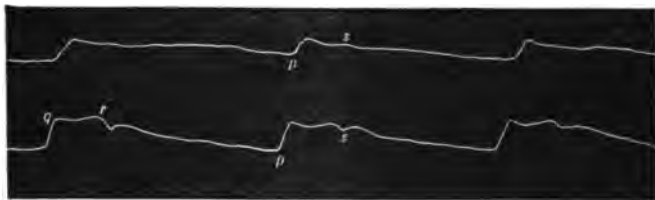


Fig. 6.

In fig. 7 we have two series of pulse-curves. A is taken from the A. carotis, and B is registered by the periodic changes in bulk which, according to Mosso's¹ experiments, the finger undergoes under the influence of the rhythmic pulsation of the blood.

¹ Mosso, *Reale Accademia di Scienza di Torino*, vol. xi.

Again, in both series the distance ps is equal. Yet in the finger we are quite at the end of the artery, where the first reflected wave covers wholly the primary one.

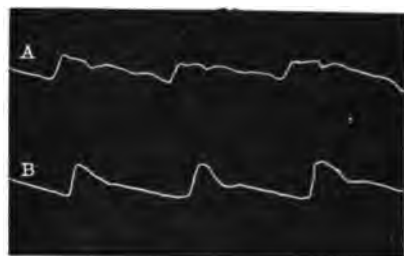


Fig. 7.

Fig. 8 is a copy of two of Marey's curves of the A. carotis and the A. femoralis of a horse.¹ In both curves the horizontal distance ps is the same, though the distance from the heart to the point of the A. carotis is considerably smaller than that to

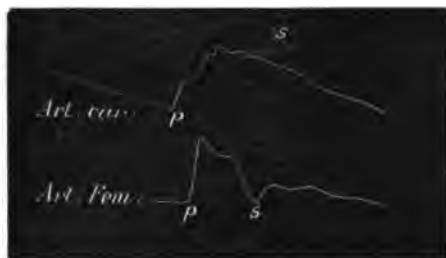


Fig. 8.

the point of the A. femoralis. So it is proved that dicrotism cannot be caused by the first reflected wave, nor by any of the reflected waves of *uneven* order.

Can it be the influence of the reflected waves of *even* order for which is found that the retardation is the same for all points of the tube?

This also cannot be the case, for not only in pulse-curves of the same person, but also in those of different persons of very different stature, the distance ps remains unchanged. See fig. 9, where are given two series of pulse-curves of the A.

¹ Marey, *loc. cit.*, p. 226.

carotis of two persons whose stature differed more than 30 cm.



Fig. 9.

Likewise in fig. 10, where we see two series of radialis curves of two persons of 179 and 139 cm. stature. In both series the distance *ps* amounts to 4 mm.



Fig. 10.

The radialis curves of two different persons of 180 and 160 cm. stature were registered directly after another, and exactly in the same manner on the same glass plate, then fixed with varnish, and afterwards projected by means of an electric lantern 240 times magnified on a screen that was divided in cm².

Measuring on the magnified images of the two series of pulse-curves the distance *ps*, I found—

A = 180 cm.	B = 160 cm.
<i>ps</i> = 96 "	96 "
96 "	96 "
95 "	97 "
96 "	96 "
96 "	97 "
97 "	96 "
95 "	95 "
—	—
Mean value 96 "	96 "

At last I have photographed, greatly magnified, the radialis curves of two persons, the one being a dwarf of 132 cm. stature, the other being a normal person of 162 cm. Both photographs are made and magnified in the same manner. In fig. 11 we see true facsimiles of these photographs. A is the radialis curve of the normal man, B that of the dwarf. They have an identical scale, and we see now that the point *s* in both curves falls on the ninth division.

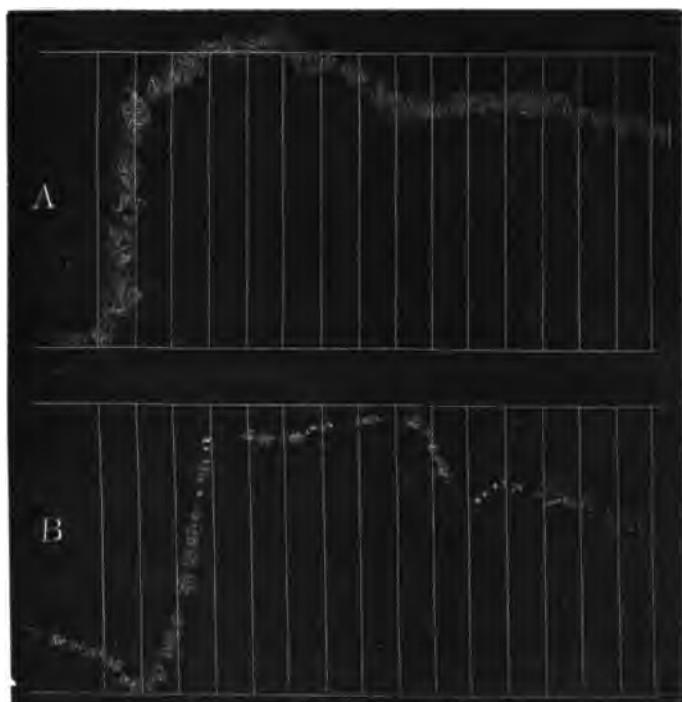


Fig. 11.

Thus it is proved that in arteries of different length the distance between primary and dicrotic waves is the same, a result that is wholly contrary to any idea of peripheral reflection.

9. When the dicrotic wave is not due to peripheral reflection, it cannot be otherwise than a secondary elevation in the primary curve, caused by some circumstances which accompany the heart's beat. In that case only the distance *ps* will be the

same for all pulse-curves of normal men. This conclusion would be inevitable if some authors did not presume that in the motion of fluids in elastic tubes there exists still a wholly different sort of waves, which are *neither primary nor reflected*, and which Landois¹ calls "Rückstosswellen," and Moens² "Schliessungswellen"—rebounding waves or closing waves.

Without occupying ourselves with the somewhat obscure theories which the said authors give of the generation of these presumed waves, I will shortly prove that the Landois' "Rückstosswellen" are nothing else than the second reflected waves; and that likewise the Moens' "Schliessungswellen" are identical with the fourth reflected waves.

To prove the first part of this proposition, I take the experiment described in Landois' work, *loc. cit.*, p. 109, fig. 19. From the there given data I calculate the modulus of elasticity of the used tube, E, on 7400 gram., and then by means of Young's rule, because $x = 0.5$ cm. and $d = \frac{4}{30}$ cm., the velocity of the wave-motion, c , on 10 metres nearly. The elastic tube was $(255 + 116)$ or 371 cm.; hence the retardation of the second reflected wave, according to § 7, $\frac{2l}{c} = \frac{742}{1000} = 0.742$ sec. But

Landois remarks (*loc. cit.*, p. 76) that the velocity of the sphygmograph's glass plate was 9 mm. per second; 0.742 sec. corresponds thus with $0.742 \times 9 = 6.68$ mm. on the registered curve. Now, we find in Landois, fig. 19, nearly 7 mm. behind the primary elevation, the beginning of his "Rückstosswellen." Therefore this is nothing else than the second reflected wave.

That Moens' "Schliessungswelle" is identical with the fourth reflected wave, of which we proved in § 7 that the retardation for all points of the tube is $\frac{4l}{c}$ sec., is easily shown by Moens.³

Moens remarks that the elastic tube was 670 cm. long, and that for the first series of curves the sphygmograph was placed 300 cm. from the tube's origin, and for the fourth series on 620 cm. from the same point, which differs:

$$620 - 300 = 320 \text{ cm.}$$

¹ Landois, *Die Lehre vom Arterienpulse*, Berlin, 1872.

² Moens, *loc. cit.*

³ Moens, *loc. cit.*, p. 68.

By measuring in Moens, the difference between the beginning of the primary wave in the first and in the fourth series of curves, I find a retardation of 1·8 mm. This 1·8 mm. will represent thus in the figure the time in which the wave has run through a space of 320 mm., from which we conclude that four times the length of the tube, or 2680 cm., corresponds to

$$\frac{2680}{320} \times 1\cdot8 = 15 \text{ mm.}$$

But exactly 15 mm. behind the primary wave we find, in all the four series of curves, Moens' so-called "Schliessungswelle," A; hence this wave is nothing else than the fourth reflected wave, as Moens himself has declared in his "Inaugural Dissertation," which precedes his above-mentioned book in the German language by one year. There, on page 45, he says—"The length of a whole 'Schliessungswelle' I found four times as great as the tube's length."

Thus, the waves and elevations which Landois and Moens have found in their experiments with elastic tubes were all due to peripheric reflection, which peripheric reflection fails wholly in the arterial system, and therefore cannot be the cause of the pulse dicrotism.

10. Now, there remain yet the waves which Marey calls the *secondary waves*, and which are indicated by Foster¹ by the name of *waves of oscillation*.

These are the same waves which are already discovered by Weber in free water and in rabbits' guts. They are small waves, which are formed *behind* and at the cost of the primary wave, and they represent the mode in which the elastic tube regains its equilibrium when the fluid jet has ceased to work. A similar after-vibration shows every pendulum, every chord, every sphygmograph; in short, every body that possesses a stable condition of equilibrium. Ordinarily, these vibrations are called the *proper* motion of the body.

E. H. Weber did not find these secondary waves in india-rubber tubes; and Marey only then when the tube was very weak (small value of E) and the primary impulsion very strong. In my experiments with elastic tubes I found wholly confirmed

¹ Foster's *Text-book of Physiology*, 2nd edit., p. 188, fig. 28.

the results of Marey. In the rule, the secondary waves are unimportant and invisible, unless the elastic tube is very wide and very weak.

For this reason, we may not attribute the pulse dicrotism to waves of oscillation.

11. *The pulse dicrotism is caused by the closure of the semilunar valves.* To prove this, we firstly demonstrate that the point *s* of the pulse-curve (see figs. 8 and 11), which is the commencement of the dicrotic elevation, indicates the moment in which the valvulæ semilunares are closed.

Therefore in my experiments with elastic tubes I arranged the *metallic* valve between the balloon and the tube in this manner, that, on closing, an electric current was interrupted, which, by the aid of a large Rumkorff inductor, caused an electric spark to spring from the registering lever through the blacked paper to the registering drum. Thus, a visible sign on the curves indicated exactly the moment of the valve being closed.



Fig. 12.

See fig. 12, where, in eight successive curves, the electric spark has marked rigorously the moment of closure of the tube's valve. This moment is also that of the point *s*, the beginning of the dicrotic wave.

Secondly, I have put a sphygmograph with air-transport on the carotid of a person whose heart-sounds I auscultated with a stethoscope. On the sounds of the heart I brought the hand in a rhythmical motion, and, when I believed this motion to be isochrone with the sounds, the hand was made to press on an ordinary telegraph key, by which an electric current was broken, which caused an electric spark to mark in the sphygmographical curves the exact moment of the *second* heart sound. According to all physiologists, this second heart-sound concurs with the closure of the "valvulæ semilunares," and so I proved that this closure indicates also the beginning *s* of dicrotism.

See fig. 13, where, in some sphygmographical curves, the

electric spark has made its appearance just at the point *s* of the pulse-curve.

Bringing this experiment, which I have often repeated, in connection with that of Garrod,¹ mentioned in *Foster's Text-book*,² it cannot be doubted that the origin of the dicrotic wave falls at the same instant as the closure of the semilunar valves, and then, in relation to all the facts, united in § 8, only one explication offers itself inevitably to the mind, *i.e.*, that this closure is also the cause of the said elevation.



Fig. 13.

Dr Burdon Sanderson's assertion,³ that even in the absence of any valve the dicrotic elevation is formed, is most certainly erroneous.

See fig. 14, where on the same line are traced two artificial pulse-curves, the first with semilunar valve, the second without



Fig. 14.

it. In the first curve we see clearly at *t* the dicrotic elevation, but in the second curve it fails entirely. The furrow at 1 is in both traces the first reflected wave, here dissimilar, because the tube's end is open. Only then, when we erroneously bring into consideration this reflected wave, which, I repeat, fails in the arterial system, we can assert that also in the second case an

¹ *Proc. Roy. Soc.*, vol. xix. p. 318.

² *Foster, loc. cit.*, p. 189.

³ *Foster, loc. cit.*, p. 140.

elevation is formed. But this elevation is only the rising to the normal level, when, in the absence of the valve, the fluid pressure is sunken far below it. This rising resembles a wave only for the following furrow, due to the first reflected wave.

Sanderson's reasoning brings the dicrotic elevation to the order of the secondary waves, of which we have mentioned that they are insignificant in ordinary circumstances.

12. In most pulse-curves we find, besides the dicrotic wave, also another elevation called the *predicrotic* wave, and marked in figs. 6, 9, and 11 with the character *r*. Foster¹ says—"This predicrotic wave is much more variable than the dicrotic wave, and its origin is obscure." Likewise judge Moens and others. Marey² regards it as to be of little importance.

I ascribe it to the proper motion of the sphygmograph, or, rather, it is the elevation *g* (figs. 6, 8, 9, and 11) which is erroneously written by the sphygmograph, the registering lever springing too high under the influence of its inertia.

The lever's point ought to trace the curve *pq'lmrstu*, but owing to its great upward velocity at *p*, it rises faultily too high unto *q*, from which height it soon falls back to *m* and *r*. Thus it seems as if the point *r* makes part of a secondary elevation *mrs*, while in reality this point *r* is the summit of the primary wave and the end of the systole. The shape of the pulse-curve is deformed by the fault of the sphygmograph.

It is believed that the exact form is *pqmnstu*, with a secondary elevation, *mrs*, while in reality it is *pq'lmrstu*, with no secondary wave at all, except that of the sphygmograph itself, *q'qm*.

That every sphygmograph, when in rapid motion, makes too great excursions and thus registers falsely, is observed by all experimentalists, and Donders, Grashey, and others have already given rules for discerning these *proper* motions of the instruments. The best instrument is that which has the smallest proper motions, but none is exempt from them. Grashey³ discovered that for every instrument there exists a maximal velocity, *V_m*, of the lever, above which proper motions take place

¹ Foster, *loc. cit.*, p. 139.

² Marey, *loc. cit.*, p. 221.

³ Grazi: *y*, *loc. cit.*, p. 5.

without exception. For his sphygmograph system (Béhier), this maximal velocity was 12 cm. per second, for my sphygmograph, with air-transport, V_m was 13 cm.

Now, when we calculate the velocity with which is registered the first upward stroke, pq , of the carotis curves (figs. 6 and 9), we find more than this maximum, for in fig. 6 the horizontal projection of pq is 1 mm., which, for a velocity of the registering drum of 30 mm. per second, represents a difference in time of $\frac{1}{30}$ second; but the height of pq is 5 mm.; in $\frac{1}{30}$ second, a space of 5 mm. gives in 1 second a space of 15 cm. Hence it is certain that in writing the first upward stroke, pq , the registering lever has risen too high.

13. The exact form of the pulse-curve is that of $pq'lmrstu$, and may be explained thus—

When the systole begins, the heart suddenly throws into the aorta a great mass of blood, which gives rise to a sudden increase of pressure; the sphygmograph traces the upward line pq' .

This blood dilates the aorta and brings into action its elastic force, which reacts on the inflowing blood. Hence the pressure must increase more slowly than before, and the sphygmograph traces $q'lmr$.

At last the aorta is so strained that the efference of blood towards the periphery grows equal to the afference from the heart, and for shorter or longer time the blood-pressure remains the same till the beginning of the diastole.

Then, while the dilated aorta drives the blood with great force, suddenly, not only the efference of blood is stopped, but also the dilating heart presents to the blood a space in which it can flow without hindrance. Hence the blood-pressure sinks very rapidly, and the sphygmograph describes a vertical line, rs . So r indicates always the beginning of the diastole, as we can see distinctly in the experiments with the balloon and an elastic tube. When fixing the eye on the registering lever while we are squeezing the balloon in different manners, we see that this lever makes a downward stroke at every diastole.

The blood, in flowing back to the dilating heart, soon shuts the "valvulæ semilunares," and so itself puts an end to its backward motion. Then, again, it finds no other way than to the

periphery, and the pressure sinks with much less rapidity. According to my spark-experiments the point *s* characterises the moment of closure of the valves.

This point *s* divides the pulse-curve in two different parts. The first part represents the forced motion under the influence of the heart's work; the second part represents the free motion of the blood in the arteries when it is insulated from the centrum.

When from the point *s* the blood efference could take place uniformly, the form of the pulse-curve should be a straight line *svu*, which indicates the velocity with which the over-filled vessel regains its equilibrium. At best this straight line might be rippled by small waves of oscillation, occasioned by proper motions of the sphygmograph and of the vessel itself. But, before this happens, there exists a reason why the dicrotic wave *stu* is formed. This reason is the shock with which the blood strikes on the closed valves when reflowing to the heart during the diastole. By this shock the blood rebounds into the aorta, and causes a new dilatation, which is indicated by the sphygmograph in *stu*.

When these valves are removed there can be no trace of rebounding, and the dicrotic wave fails wholly, as is proved by fig. 14. In that case the pulse-curve takes sometimes the form fig. 15, where *q'qm* and *s'st'* are due to proper motions of the sphygmograph, while the true form is *pqlmrs't'u*. It is possible to confound this false elevation, *st'u*, with the true dicrotic wave *stu* of the above paragraph, and then it seems as if the removing of the valves had not altered the dicrotic elevation.

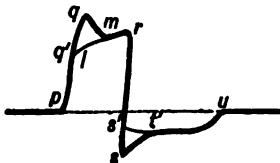


Fig. 15.

There is still another case in which the dicrotic wave fails, i.e., when at every systole the left heart contracts itself till it is wholly empty. Then the aorta receives no more blood from the ventricle, while it continues to drive the blood

to the peripheric vessels; the blood-pressure, after having reached its maximum, must decrease in that case slowly and uniformly till the normal condition is attained. See fig. 16

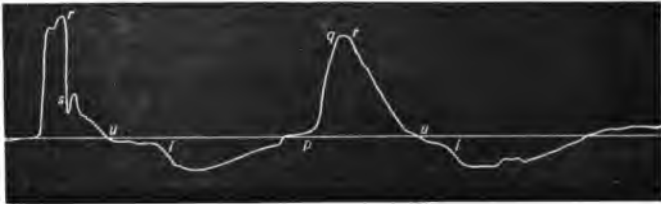


Fig. 16.

where are given two curves made with my artificial scheme—the first with a short systole, directly followed by the diastole; the second with a short systole, followed by a pause of long duration, during which the blood-pressure sank slowly and uniformly to the minimal value. In the first curve we distinctly see the vertical line *rs* and the dicrotic elevation; in the second the curve sinks directly and uninterrupted till *u*. At best this line *ru* may be rippled by small waves of oscillation. This last form is never found in natural pulse-curves, and hence I conclude that in man the heart is far from being emptied at every systole.

To this conclusion I may now add the following:—

1. A slowly-rising upward stroke, *pq'*, indicates a great rigidity of the vessels.
2. When *mr* is inclined downwards, there exists a considerable effluence of the blood,—the capillaries are open wide.
3. In that case the line *svu* is also more steeply inclined downwards.
4. A long line, *rs*, proves that the semilunar valves are leaky, or very flexible and soft.
5. In that case the dicrotic wave is inconsiderable or failing.

All that is said in this paragraph regards the pulsation in the beginning of the aorta.

How this original motion generates a progressive wave-motion throughout the whole vascular system, by which, at its proper

time in every point of the system a similar pulsation is caused, all this is most satisfactorily explained by E. H. Weber in his paper of 1850.¹

14. There is in the pulse-curve no certain sign by which the blood-pressure is indicated.



Fig. 17.

The two curves (fig. 17) are registered by the same sphygmograph directly after one another, but for the second curve, *b*, the pressure in the elastic tube was 3 metre water higher than for the first curve, *a*.

In comparing these two curves, we found that the only difference is that of the absolute size. But in natural pulse-curves this absolute size escapes almost always every observation.

Therefore it is desirable to aid in this respect the sphygmograph by measuring the blood-pressure with a separate instrument. For animals there exist already many instruments of that sort,—the manometer of Hales, Poiseuille and Marey;² Ludwig's kymographion;³ Fick's spring manometer;⁴ Talma's tonometer;⁴ Marey's registering metallic manometer,⁵ &c. Some of these instruments give good and trustworthy results.

But when it is asked to determine the blood-pressure in the uninjured arteries of man, the difficulties which arise are great.

Firstly, the arteries are more or less covered with soft and pliable parts; secondly, we often miss here a solid, unmovable foundation on which the artery can be pressed; and, thirdly, the arterial shell, like in every elastic tube, has, also in the *undilated* state, a tension which is variable and unknown.

No wonder that none of the instruments destined for this sort of experiment can be said to satisfy the requirement. I

¹ Weber, *Ber. Süchs Gesells.*, 1850.

² Marey, *loc. cit.*, p. 170.

³ Foster, *loc. cit.*, pp. 100, 120.

⁴ *Pflüger's Archiv*, Bd. xxiii.

⁵ Marey, *loc. cit.*, p. 180.

am here referring to the instruments of von Waldenburg,¹ von Basch,² and Marey.³

Those of von Basch and von Waldenburg are both founded on the fact that, when an increasing external force is exerted on an artery, at last this artery will be pressed together, and the blood circulation will be stopped. At this moment the known external force is a measure for the inner pressure of the blood. Von Waldenburg exercises the force by screwing a piston on the artery; von Basch presses a certain mass of water into an untensile membrane which covers the artery. Both observe a little object fixed peripherically on the artery, and continue the pressure till this object has ceased to move up and down.

In this manner I have made a great many experiments on different india-rubber tubes filled with water, which was brought in pulsation.

Here I had to do with a solid foundation, on which the tube was fixed, the inner pressures could be varied within large limits, and I could experiment first with the empty and then with the filled tube, so as to ascertain the tube's proper tension; yet the faults which were made were never less than 10 per cent. The great difficulty, as also Zadek⁴ observes, lies in the determination of the exact moment when the tube is closed. When it is tight for weak pulsations, a stronger one opens it again, and brings the object in motion.

According to these experiments, I cannot possibly agree with von Basch, who presumes that by this method trustful absolute measures can be made;⁵ and I must agree wholly with Zadek and Christeller,⁶ who both recommend it only for relative measures, and then it can sometimes lead to interesting conclusions.

But, for relative measures, we need not von Basch's costly and composite apparatus, a very simple instrument for this use being designed in fig. 18. It is a copper cylinder, A, of 14 mm.

¹ Von Waldenburg, *Die Messung des Pulses und des Blutdruckes am Menschen*, 1880.

² Von Basch, *Zeitschr. f. klin. Medicin*, Bd. ii. p. 80.

³ Marey, *Travaux du laboratoire*, vol. iv. p. 126.

⁴ Zadek, "Inaug. Diss.," Berlin, 1880.

⁵ Von Basch, *Zeitschr. f. klin. Medicin*, Bd. iii. p. 502.

⁶ Christeller, "Inaug. Diss.," Berlin, 1880.

diameter and 80 mm. of length, in which is put a steel spiral spring B, that presses against a piston *f*, to which is fixed by the rod D the piston E. In the copper cylinder is made a longitudinal groove, on the edge of which is marked a divided scale, giving in grams the pressure which the spring exerts on the piston.



Fig. 18.

Now, when we lay a finger on the artery, and taking the copper cylinder with the other hand, place the piston E, on the finger-nail, then, by pressing the cylinder downward, we exert an increasing force on the vessel, and feel how the pulse grows stronger and stronger till it reaches its maximum of force; then it decreases, and at last, directly under the finger, the pulsations are wholly extinguished, not at the central side of the finger, not always also at the peripheric side, but immediately under the finger there is total stillness. Then we read on the divided scale the number of grams of the force exerted, which is a measure for the pressure of the blood. With some exercise this small instrument gives good results, and I doubt not that a physician, when every day applying it to his patients, would in many cases find it useful.

The method of Marey for absolute measures rest on the fact that, when we put our finger in a closed water vessel, the arterial pulsations will communicate themselves to the water, which begins to oscillate. These oscillations are observed in a capillary tube fixed to the water vessel.

When now the outer water pressure is increased, we see these oscillations grow larger and larger; but soon a maximum is reached, and then the oscillations decrease, till at last they vanish entirely.

Now, it is easy to demonstrate that at the moment the oscillations have reached their maximum the inner pressure of the blood equals the outer pressure of the water. For in these experiments the inner pressure must balance the tension of the dilated vessel as well as the outer pressure of the water. So,

when the dilation of the artery's radius is Δr , its tension is by form (5)

$$P = \frac{Ed}{r^2} \Delta r \text{ per cm.}^2;$$

and when the minimal inner pressure of the blood is h_i cm. of mercury and the outer pressure h_o cm. of mercury, we have

$$13,6h_i = 13,6h_o + \frac{Ed}{r^2} \Delta r. \quad (6).$$

Likewise we have for the maximal pressures

$$h'_i \text{ and } h'_o$$

$$13,6h'_i = 13,6h'_o + \frac{Ed}{r^2} \Delta' r.$$

Hence the amplitude of the outer oscillations is

$$h'_o - h'_i = (h'_i - h'_o) - \frac{Ed}{r^2} (\Delta' r - \Delta r),$$

and has its maximal value for

$$\Delta' r = \Delta r.$$

But $\Delta' r$ cannot be equal to Δr unless

$$\Delta' r = \Delta r = 0,$$

so (6) gives

$$h_i = h_o$$

$$h'_i = h'_o.$$

In order to try this method, which, only in short, is indicated by Marey, I have devised the simple apparatus (fig. 19), wholly made of glass.

It is a glass tube A for receiving the pulsating finger.

To A is soldered a narrow tube, which ends in a vertical tube D, while it has in B a vertical capillary tube B, and in C a good shutting cock.

This cock being shut, the tube D is filled with mercury.

Then the finger is put into the tube A, to which it must shut tightly, without closing the arteries. This shutting without closing is the greatest difficulty, which can be overcome only by choosing the tube A of proper dimensions, and rubbing the finger with fat.

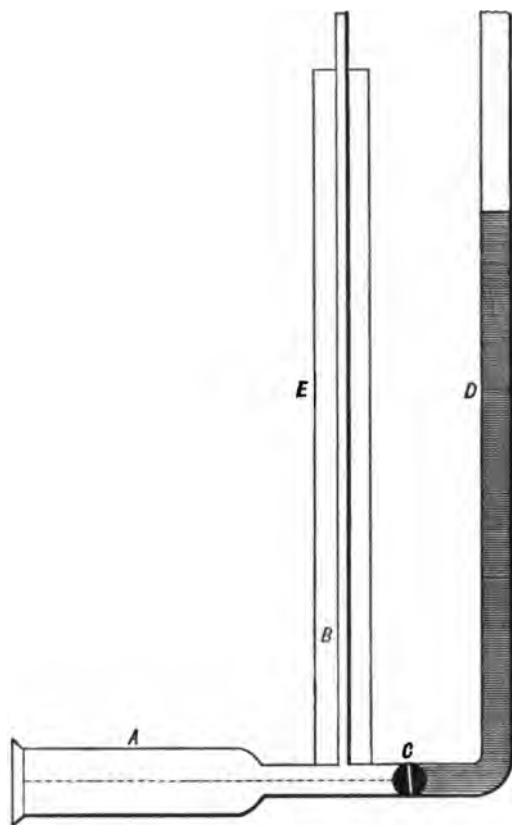


Fig. 19.

Now, while turning the apparatus in the proper position, we open the cock C, and permit the mercury to fill the space between the tube A and the finger. The air escapes then by tube B, and at last, not only all cavities are filled, but also the mercury has risen in the capillary tube B to a certain height.

Then the cock C is closed, and the apparatus screwed to the

table by means of a wooden stand, to which the tube A is fixed. This is done in order to bring the finger in an unmovable state.

Now the oscillations in B soon become visible, and can be measured on the divided scale E.

Then we open for a moment the cock C, bring a new quantity of mercury into the apparatus, and observe again the oscillations of the mercury in B.

So we continue to bring new quantities of mercury into the tube A until we see decrease the oscillations, by which is proved that we have passed the maximum.

Now, by emptying the tube D and opening the cock C, we bring the mercury back to tube D, and repeat the experiment. In a little time we can in this manner determine the absolute value of the blood-pressure in the arteries of the finger, without all those faults that adhere to the method of von Basch and von Waldenburg.

Of the many results thus obtained I give here an example:—

Sex.	Age.	Arterial blood-pressure in mm. Hg.
Masculine, . .	50 years.	115
” . .	47 ”	110
” . .	21 ”	100
” . .	17 ”	116
Feminine, . .	49 ”	95
” . .	18 ”	100
” . .	20 ”	105

Von Waldenburg finds 200–268 mm. Hg.

Von Basch ” 102–190 ”

Zadek ” 70–144 ”

Thomas Young gives the value found by Hales, *i.e.*, 5 feet of blood, or 118 mm. of mercury. Now, when we observe that Faivre has found during computations a blood-pressure of 120 mm. Hg, it seems certain that my figures cannot be far from the reality, and that also in this matter Young gave the true value.

15. The area of the pulse-curve is a measure for the quantity of blood that flows during one heart-beat through the given artery.

To prove this, I observe that ABCDEF, fig. 20, being a piece of the undilated artery of such a length that the wave-motion of the blood travels in one heart-beat from A to C, then, during the passage of the wave, the artery is dilated to the form AB'CDE'F, and the quantity of blood that has passed is represented by the volume of the body, formed by the rotation of the plane figure AB'CBA round the tube's axe OO'.

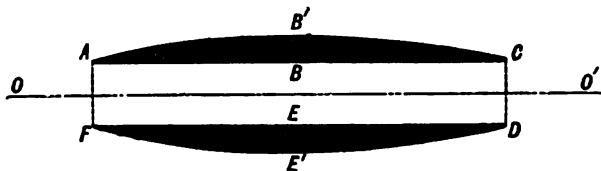


Fig. 20.

According to Guldin's rule, this volume is found by multiplying the area of the figure AB'CBA with the line described by the centre of gravity.

Hence, putting the radius of the tube r and the area of the figure AB'CBA, A , and the blood quantity which passes during one heart-beat through the artery, q , we will have nearly

$$q = A \times 2\pi r.$$

But the curve AB'C is formed by the different dilations which at the *same time* the *successive points* of the artery undergo, and, according to the proprieties of every progressive wave, the same dilations, which occur at the *same time* in *different points* will also be found, in *succession of time*, at the *same point*; i.e., the same series of dilations which form the curve AB'C pass also successively under the sphygmograph's piston. Hence the sphygmograph traces a curve similar to the curve AB'C, with this difference, that the velocity of the registering plate v , comes in the place of the velocity of the blood-wave c , and that the sphygmograph's lever magnifies n times the motion of the piston. So, when O is the area of the pulse-curve itself, we have

$$A : O = c : nv ; \text{ or,}$$

$$A = O \times \frac{c}{nv}, \text{ and}$$

$$q = O \times 2\pi r \times \frac{c}{nv} \quad . \quad . \quad . \quad . \quad . \quad (7).$$

Here, however, we must observe that O signifies the area which the pulse-curve would have if the sphygmograph did not press on the artery. This pressure exerts a considerable influence on the magnitude of the displacement. According to (6), an increasing outer pressure firstly augments, but afterwards diminishes, this displacement; and, when the outer pressure has reached a fixed value, the amplitude of the piston is a maximum. There exists a constant relation between the maximal displacement, and that in absence of the sphygmograph. Therefore, we can put

$$O : O' = O_m : O'_m,$$

where O_m and O'_m represent the areas of the pulse-curves, traced during the maximal displacement; and then we have for the quantities of blood, q and q' , which pass, in different circumstances during one heart-beat through the same artery—

$$q : q' = O_m : O'_m. \quad . \quad . \quad . \quad . \quad . \quad (8).$$

Every series of similar and symmetrical curves registered by the same sphygmograph, when put in maximal displacement, proves that during the experiment the quantity of blood q , which passes in one beat through the artery, has remained equal and constant. Even the results of different days are in this manner comparable with one another.

The measuring of the area of the thus made pulse-curves by means of a glass netmicrometer, divided in $\frac{1}{10}$ mm. can lead to many conclusions about the condition of the heart and arteries.

For this quantity q is the same that under the name of *blood velocity*¹ is determined on animals by Volkmann, Ludwig, and Dogiel with the "Stromuhr," by Vierordt with his "hæmotachymeter," by Chauveau with the "hæmodromometer," and by Marey with his "hæmodromographe."²

The proportion (8) gives now the means to measure the same quantity for the unhurt arteries of man.

16. We have found now the means for determining, at least

¹ When V represents the so-called blood-velocity, N the number of heart-beats per minute, r the radius of the artery, then we have

$$V = \frac{qN}{60\pi r^2}.$$

² Marey, *loc. cit.*, chap. xix.

relatively for every human artery, the pressure of the blood P , and the quantity of blood q , which passes in one heart-beat through the artery.

When we express

P in cm. of mercury,

q in cm.;

then, according to (3) we have for the tone w of the corresponding capillaries—

$$w = \frac{P}{qN}$$

$$\text{and,} \quad w:w' = \frac{P}{qN} : \frac{P'}{q'N'} \dots \dots \dots (9);$$

$$\text{or,} \quad w:w' = \frac{P}{NO_m} : \frac{P'}{NO'_m} \dots \dots \dots (10),$$

by which we can compare the tone of the capillaries of different arteries of different men. The unity, in which w is expressed is the friction in a tube through which passes, in one minute, 1 cm. of blood, when the pressure at the beginning of the tube is 1 cm. of mercury higher than at the end.

According to the experiments of Poiseuille,¹ this tube would be of 1 mm. diameter and 123 cm. of length for water. Young taxes the viscosity of blood four times that of water; so this would give for our unity a tube of 1 mm. diameter and 31 cm. long.

Later experiments of Helmholtz and Piotrowsky² gave for water a tube of 1 mm. diameter and 140 cm. of length; and recent researches of Ewald³ indicate the viscosity of blood $\frac{100}{41}$ times that of water; so our unity would be that of a tube of 1 mm. diameter and 57 cm. of length, or nearly that of a tube of

1 mm. diameter and $\frac{1}{2}$ metre long.

Dogiel⁴ finds for a rabbit's carotid q , pro sec., $\frac{1}{2}$ cm³., and P 9.2 cm. of mercury.

¹ *Mem. des savants Etrangers*, tome ix., 1846.

² *Wiener Sitz. Ber.*, 1860.

³ See Hermann, *Lehrb. Physiol.*, p. 68.

⁴ Degiel, *Ber. Sächs. Gesellsch.*, 1867, p. 200.

Hence,

$$w = \frac{9.2}{60 \times \frac{1}{2}} = 0.31.$$

So the friction of the blood in all the capillaries of the rabbit's head is nearly 15 per cent. of our unity, or that of a tube of 1 mm. diameter and $7\frac{1}{2}$ cm. long.

17. When in one second $\frac{qN}{60}$ cm. of blood are driven through an artery of r cm. radius under a pressure of P cm. mercury, the force exerted is

$$P \times \pi r \times 13.6 \text{ grams;}$$

the way, which is run through, is

$$\frac{qN}{60 \times \pi r^2} \text{ cm. ;}$$

hence the *work* done is

$$L = \frac{13.6 \times PqN}{60} \text{ gr. cm. per second ;}$$

$$\text{or } L = \frac{PqN}{441176} \text{ kilogrammeter per second ;}$$

$$\text{or } L = \frac{PqN}{61014} \text{ foot-pounds per second ;}$$

$$\text{or } L = \frac{PqN}{33560000} \text{ horse-power ;}$$

$$\text{or putting } k = \frac{1}{33560000} ;$$

$$L = kPqN \text{ horse-power, (10).}$$

For another artery we have

$$L = kPq'N ; \text{ and}$$

for the whole arterial system

$$L = kPN\Sigma(9) ;$$

or, Q being the total quantity of blood which the heart ejects in one beat,

$$L = kPNQ, (11).$$

When we suppose with Young and Fick that Q is nearly 50 cm³, then for 68 beats per minute and 12 cm. Hg blood-pressure, the total work done by the left heart is:¹

$$L = \frac{12 \times 68 \times 50}{33560000} = \frac{1}{822} \text{ horse-power,}$$

and the total tone

$$W = \Sigma(w) = \frac{12}{50 \times 68} = \frac{1}{283};$$

i.e., all the capillaries of the man's vascular system present to the whole blood circulation a resistance equal to that of a tube of 1 mm. diameter and $\frac{500}{283}$, or 1.76 mm. long.

When we suppose a constant relation between the total quantity of blood Q , and that of one artery q , we can write

$$Q = fq$$

and

$$L = kfPNq, \text{ or, according to (8),}$$

$$L : L' = PNO_m : P'N'O'_m \dots \dots \dots (12).$$

So it is clear that we can examine both the condition of the heart and the capillaries by measuring relatively

$$P, N, \text{ and } O_m,$$

$\frac{P}{N \times O_m}$ being a measure for the capillaries' tone, and $P \times N \times O_m$ measuring the heart's work.

Zadek² has proved that in fever the blood-pressure is increased. Out of the sphygmographical curves which Marey³ gives on p. 565, I conclude that O_m decreases, but that N and also $N \times O_m$ increase. So the heart's work is greater in fever than in a normal condition.

18. In the preceding paragraph we have tried to find by experiment the actual state of heart and vessels; now we will

¹ I prefer the values given by Young (45) and Fick (53-72) above those of Volkmann and Vierordt (180), because the latter suppose that the heart is wholly emptied at every systole, which is contradicted by the form of the pulse-curve. See § 13.

² Zadek, *loc. cit.*, p. 44.

³ Marey, *loc. cit.*, p. 565.

invert the question, and ask how changes in the condition of heart and vessels influence the circulation, hereby taking into account that the left heart disposes of no more blood than is ejected by the right heart through the lungs. According to the formulæ (3) and (11), we have

$$P = QNW$$

$$L = kPQN.$$

Likewise, when P' is the blood-pressure in the lung artery and L' the work done by the right heart—

$$P' = Q'N'W' \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

$$L' = kP'Q'N' \quad . \quad . \quad . \quad . \quad . \quad . \quad (14),$$

where W is the tone of the lung arteries,

$Q'N'$ the debit of the right heart;

but the right heart pumping in the same time in the lungs the same quantity of blood, which it receives out of the veins—

$$Q'N' = QN \quad . \quad . \quad . \quad . \quad . \quad . \quad (15).$$

The total work of the heart—

$$T = L + L' \quad . \quad . \quad . \quad . \quad . \quad . \quad (16),$$

is, like that of all muscles, variable with the resistant force. It increases for increasing pressure, but reaches a maximum, above which it diminishes.

According to the experiments of Marey¹ with an insulated turtle heart, the work of the muscle can nearly be represented by the formula—

$$L = aP - bP^2$$

where L reaches its maximum, when $P = \frac{a}{2b}$. But the pressure in the lungs being different of that in the aorta, it is preferable to put

$$T = k\{A(QN) - B(QN)^2\} \quad . \quad . \quad . \quad . \quad (17),$$

where A and B determine the actual state of the heart, and k is

¹ Marey, *loc. cit.*, p. 75.

the same figure of (10), by which the work is expressed in horse-power. Substituting (16), (11), and (14) in (17), we find

$$(18.) \quad \left\{ \begin{array}{l} QN = \frac{A}{B + (W + W')} \\ P = \frac{AW}{B + W + W'} \\ P' = \frac{AW'}{B + W + W'} \\ L = \frac{kA^2W}{(B + W + W')^2} \\ L' = \frac{kA^2W'}{(B + W + W')^2} \\ T = \frac{kA^2(W' + W)}{(B + W + W')^2} \end{array} \right.$$

So there are four quantities, on which depends the whole blood circulation, viz :—

- A and B giving the actual force of the heart.
 W „ the tone of the capillaries of the great circulation.
 W' „ the tone of the capillaries of the small circulation.

When the heart's vigour augments, then also the quantity A increases, and therewith the debit per minute QN, and the pressure P and P' in both systems of arteries.

By increasing W, P rises,¹ but P' sinks, while the debit QN decreases. For constant value of Q, this signifies that the *number* of heart-beats per minute *diminishes* when the *tone* of the vessels *increases*.

This Marey² expresses in these words:—"Le cœur bat autant plus fréquemment qu'il éprouve moins de peine à se vider." The heart acts like a steam-engine, that begins to move quicker when the resistances diminish.

When W' increases, the debit per minute diminishes, and while P' rises, P, the blood-pressure in the great arteries, sinks.³

¹ Marey, *loc. cit.*, p. 190.

² Marey, *loc. cit.*, p. 334.

³ See Marey, *loc. cit.*, p. 430.

Marey and Chauveau¹ have found—

$$P' = \frac{1}{3}P.$$

Hence

$$W' = \frac{1}{3}W$$

and

$$L' = \frac{1}{3}L;$$

and

$$T = \frac{1}{3}L.$$

Putting

$$L = \frac{1}{822} \text{ horse-power}$$

$$W = \frac{1}{283}$$

we have for the total work of the heart,

$$T = \frac{1}{616} \text{ horse-power,}$$

and the total tone of the whole vascular system—

$$W + W' = \frac{1}{212} \text{ part of our unity.}$$

¹ Marey, *loc. cit.*, p. 424.

INJURIES AND DISEASES OF NERVES. By ANTHONY A. BOWLBY, F.R.C.S., *Surg. Registrar and Demonstrator of Practical Surgery and of Surgical Pathology at St Bartholomew's Hospital.* Churchill, London. 1889.

THIS is a model work, truly scientific and practical, full of facts observed by the author, well arranged and well reasoned upon. Being "attached to a large hospital, in which his opportunities for clinical study have been practically inexhaustible," he remarks that "whatever value the work may possess is due to the fact that large numbers of patients suffering from nerve injuries of the most various kinds have been kept under constant observation for many years." In it are included the Jacksonian Prize Essay of the Royal College of Surgeons for the year 1882, and the Astley Cooper Prize Essay for the year 1886. "The book, indeed, may be said to be a condensation of the latter essay, with such further knowledge as I have gained during the last three years;" and it is one of the many evidences of the good results which have followed from these prize essays.

It commences with a brief account of the anatomy and physiology of nerves, calling attention to the nuclei on the inner side of the sheath of Schwann, as the medium through which the regeneration of nerve-fibres is effected, and to the fact that centripetal and centrifugal impulses are transmissible, under certain circumstances, by the same fibres whether motor or sensory.

His observations on the degenerative changes in nerves after injury indicate, like those of most other observers, that they "are signalised by the destruction of the myeline, the multiplication of the nuclei, and the loss of continuity of the axis-cylinder." He agrees with Hagen that the bulbs in stumps contain new nerve elements, the nerve-fibres, as time goes on, shrinking and losing their myeline; the nerves also in the stump above undergo similar change (p. 21). Similar changes also occur in the peripheral part of a divided nerve which remains separate from the proximal end. It becomes to some extent regenerated, but again tends to degenerate. The primary regenerative impulse under each of these conditions is remarkable, and not quite easy of explanation. It does not appear that the same thing has been observed to precede the atrophy in the spinal cord that follows amputation of a limb or section of nerves. Then follow cases illustrative of the union of nerves by first intention.

The chapter on the "Trophic changes caused by nerve injury" and the discussion on the theories relating to them is highly interesting. The author concludes that "nerves do exist which exert a direct trophic influence on the tissues, and that currents which convey the same are constantly passing;" but he does not think that a special set of nerves is necessary for the conveyance of these impulses, there being

no ostensible reason why the nerves of motion and sensation should not be sufficient for the purpose.

It is an important remark that the existence or return of sensibility in a part supplied by a nerve which has been divided is not to be regarded as positive evidence of the reunion of the nerve unless it be accompanied by other indications, such as a return of normal trophic conditions, muscular action, &c. It is also an important, as well as curious observation, that voluntary power in a muscle will return, when nerve union takes place, sooner than electrical excitability.

Numerous cases are related, indicating the symptoms resulting from lesion of the several nerves and the advantages of early suture. Even when union fails after the saturation, and trophic changes of many kinds take place, after complete atrophy and degeneration of the paralysed muscles, hope must not be abandoned, for recovery may yet be complete, though months may be required to bring about this favourable result. The motor functions, as a rule, take longer to return than the sensitive ones. The well and long observed cases from which these statements are made will be found at pp. 184-185.

In secondary suture, which should be attempted whenever there is good reason to believe that the wounded nerve has not united, the author recommends that the bulb of the proximal portion, which can generally be found with ease, should be divided near its upper end. The lower portion, being atrophied, is more difficult to find, and is often best sought at a distance from the cicatrix. Not more than a quarter of an inch should be removed, for the same atrophied condition which exists near the end will be found lower down, and nothing is gained, therefore, by extensive removal. Careful stretching of both parts of the nerve, without bruising, may be required to bring the ends into contact before suturing, and much may be done in this way. In reference to the time required for recovery in some of these cases, especially of motor power, it is remarked (p. 201):—"The restoration of muscle is indeed one of the most marvellous evidences of recuperative power ever met with in the human body. Muscles of which there scarcely appears to be any remains may be entirely restored in bulk and in power. It is wonderful that it occurs at all, and that it should occur rapidly is not to be supposed." Mr Bowlby has not yet met with a case in which it was not possible, by means of nerve-stretching and position, to approximate the divided and separated ends. In such a case he thinks that nerve-grafting seems to offer the best prospects of success.

The subjects of injuries of nerves from contusion, compression, stretching, fracture, dislocation, and the effects of injuries, such as neuritis, are discussed and illustrated by cases. The reflex effects engendered thereby occupy a chapter. Among the universal complications mentioned are CHOREA, of which the author finds no good evidence; but that EPILEPSY may be occasioned by nerve-injury as well as by other peripheral sources of irritation, seems to be fairly established; and a cessation of the fits has followed removal of the nerve at the part or its division higher up. With regard to TETANUS,

he expresses (p. 301) "the opinion that injury to nerve is in no way a cause of tetanus, and that, in fact, they have nothing to do with each other in the relation of cause and effect;" and in confirmation of this view he relates the recent tetanus cultivation and inoculation experiments of Ratbone and Nicolaer.

The theory of NERVE-STRETCHING and its effects, which the author believes to depend chiefly upon greater or less rupture of the nerve tubules, are discussed at some length; and an unbiassed attempt is made to estimate its value in *tabes dorsalis* and in various diseases of the brain and spinal cord, in tetanus, epilepsy, and local spasms. For neuralgia of stumps, nerve-stretching, with excision of the nerve-bulbs and adjacent parts of the nerves, has been found the most successful treatment.

In the surgical treatment of the various forms of facial neuralgia, including those paroxysmal forms to which the term "epileptiform neuralgia" has been applied, nerve-stretching has been found to give, on the whole, better results than neurotomy or neurectomy. Several nerves may require to be stretched; and it is noted that relief may not be experienced till several weeks after the operation have elapsed. "As to the excision of Meckel's ganglion, it certainly does appear to give relief when other means have failed, and the operation, although troublesome, is by no means so difficult as might be imagined. Ligation of the carotid artery should certainly not be undertaken until after a thorough trial of operations on the nerve-trunks.

Among the affections of neurotic nature attributable, at any rate in many cases, to some form of neuritis, are perforating ulcer, diabetic gangrene, Raynaud's disease, and leprosy; and the neuritis may be syphilitic, rheumatic, gouty, or alcoholic, as well as idiopathic.

The nerve-fibres which, with occasionally ganglion cells, are found in the true NEUROMATA, are said not to be continuous with those of the nerve-trunk to which they are attached, and to be commonly smaller than those of a normal nerve. The false neuromata are usually some variety of fibroma or sarcoma.

The work is illustrated by coloured drawings showing the glossy, shiny, tightly-stretched skin of the fingers and other results of nerve injury, as well as by drawings of changes in the nerves themselves under various circumstances.

We have quoted enough to show the clinical and other ground covered and the value of the work, but the amount of material accumulated can be judged only by the perusal of the book itself.

PROCEEDINGS OF THE
ANATOMICAL SOCIETY OF GREAT BRITAIN
AND IRELAND.

FEBRUARY 1890.

A MEETING of the Society was held in the Library of the Medical School of St Mary's Hospital, on Wednesday, February 26, the President in the chair. Present—Thirteen members and visitors.

The minutes of the previous meetings were read and confirmed.

F. W. Andrewes, M.D., Wilfrid Balgarnie, F.R.C.S., and Charles Devereux Marshall were elected members of the Society.

T. F. Wilson, M.B., C.M., and F. E. Withers were proposed for election at the next meeting.

Dr JAMES CAGNEY read a paper on the *Effect of Suspension upon the Spinal Column*.

He showed that in the dorsal part of the column traction produced slight elongation along the concavity of the curve, i.e., along the fronts of the bodies of the vertebræ, and slight shortening along the convexity, i.e., along the spinous processes. The axis of rotation passes transversely through the posterior wall of the vertebral body. The spinal cord lies therefore behind this axis, and in these regions is relaxed, not tightened by the process. In the cervical and lumbar regions the effect is the reverse upon the column, and as regards the bones, it nearly neutralises the dorsal alteration. But the cord lies so little in the lumbar region that the dorsal relaxation is not counteracted.

The Secretary read for Professor CLELAND a paper on *Fibro-Plates and Intervertebral Discs*, which will be found at page 373 of this volume of the *Journal of Anatomy and Physiology*.

Mr LOCKWOOD showed a specimen of *Interruption of the Small Intestine*. It was taken from a child who died four days after birth with symptoms of intestinal obstruction. The small intestine was completely interrupted about the middle of its course, and divided into two parts, the upper of which was dilated and filled in the fresh state with meconium, the lower shrivelled and empty. The mes-

entry continued without interruption, and there was no acquired disease, such as peritonitis, in the abdomen, by which the malformation could have been caused.

Professor HOWES read a paper on *Variation in the Kidney of the Common Thornback (Raia clavata): its Nature, Range, and probable Significance*, which will be found at page 407 of this volume of the *Journal of Anatomy and Physiology*.

Mr E. W. ROUGHTON exhibited a full-term foetus, showing a well-marked *Sternalis muscle* on each side, and some additional muscular slips which he thought belonged to the subclavius.

In front of the manubrium there was a quadrilateral plate of fascia, into the upper corners of which the sternal portions of the sterno-mastoid muscles were continued. From the lower corners of the plate there proceeded a well-marked sternalis muscle on each side, that on the right side reaching as low down as the third intercostal space, and that on the left side reaching as far as the fifth interspace. The sterno-mastoids were not attached to the sternum, but were distinctly traceable into the sternalis muscle on each side. The m. sternaes appeared to have no bony attachment.

Immediately behind the quadrilateral plate of fascia there was a narrow strip of muscle extending transversely across the thorax, the portion on the right side being continued into a tendon which spread out into a thin aponeurosis attached to the under surface of the clavicle, and blending with the capsule of the shoulder-joint. The portion on the left side ended externally in a small tendon which blended with the coraco-clavicular ligaments.

The gleno-humeral ligaments were well marked, but no connection between them and any part of the subclavius could be traced. The muscular slips above mentioned were held to be portions of the subclavius muscle as seen in carinate birds, and to support the theory advanced by Bland Sutton, attributing the origin of the coraco-clavicular and gleno-humeral ligaments to regression of portions of the subclavius muscle.

Mr E. W. ROUGHTON also exhibited a dissection from the museum of St Mary's Hospital showing a well-marked sternalis muscle, the tendon of which was directly continuous with that of the sternal portion of the sterno-mastoid muscle. He considered that the specimens he had shown supported the theory that the sternalis was a portion of the sterno-mastoid muscle.

Dr WILLIAM HILL exhibited the naso-pharynx of a sheep, showing the *Pharyngeal Tonsil* along the lower border of the vomer.

The meeting then adjourned.

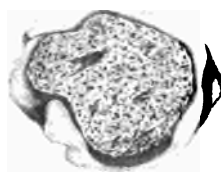


A

Fig. 1.

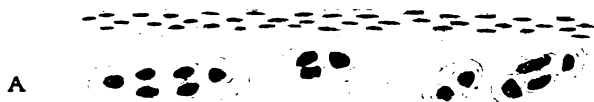


B

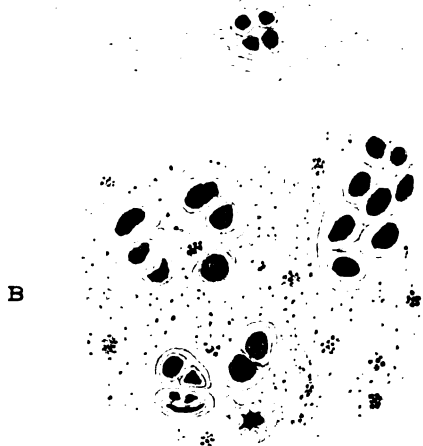


C

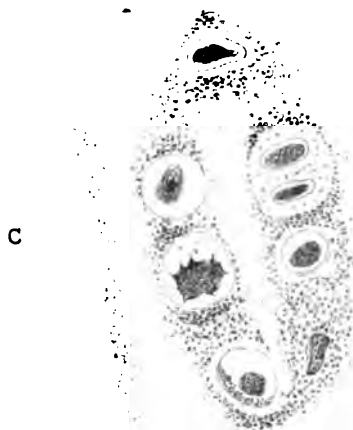
Fig. 2.



A



B



C

Fig. 1.

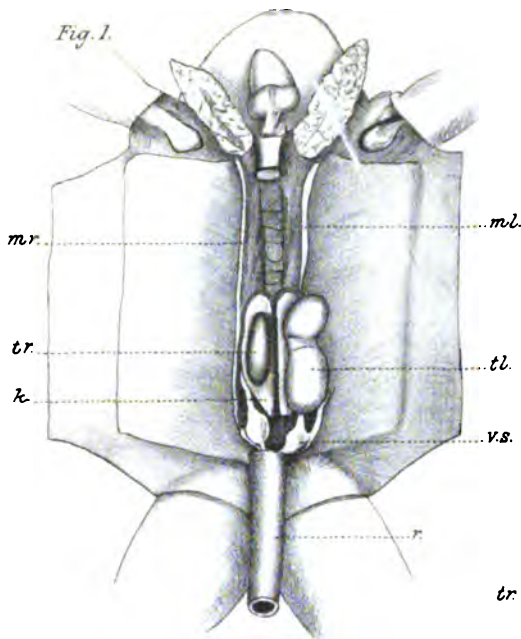


Fig. 2.

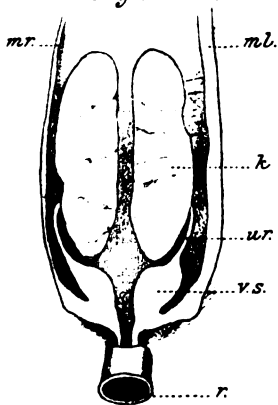


Fig. 3.

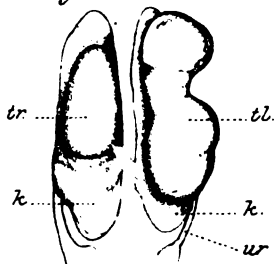


Fig. 4.

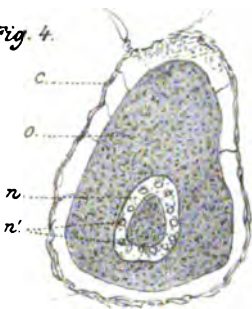


Fig. 5.

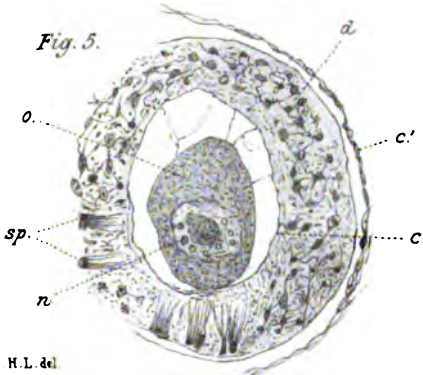
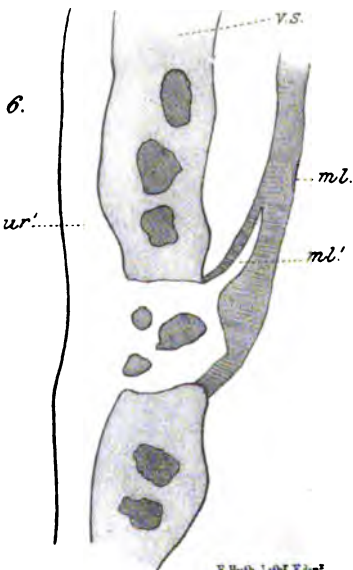


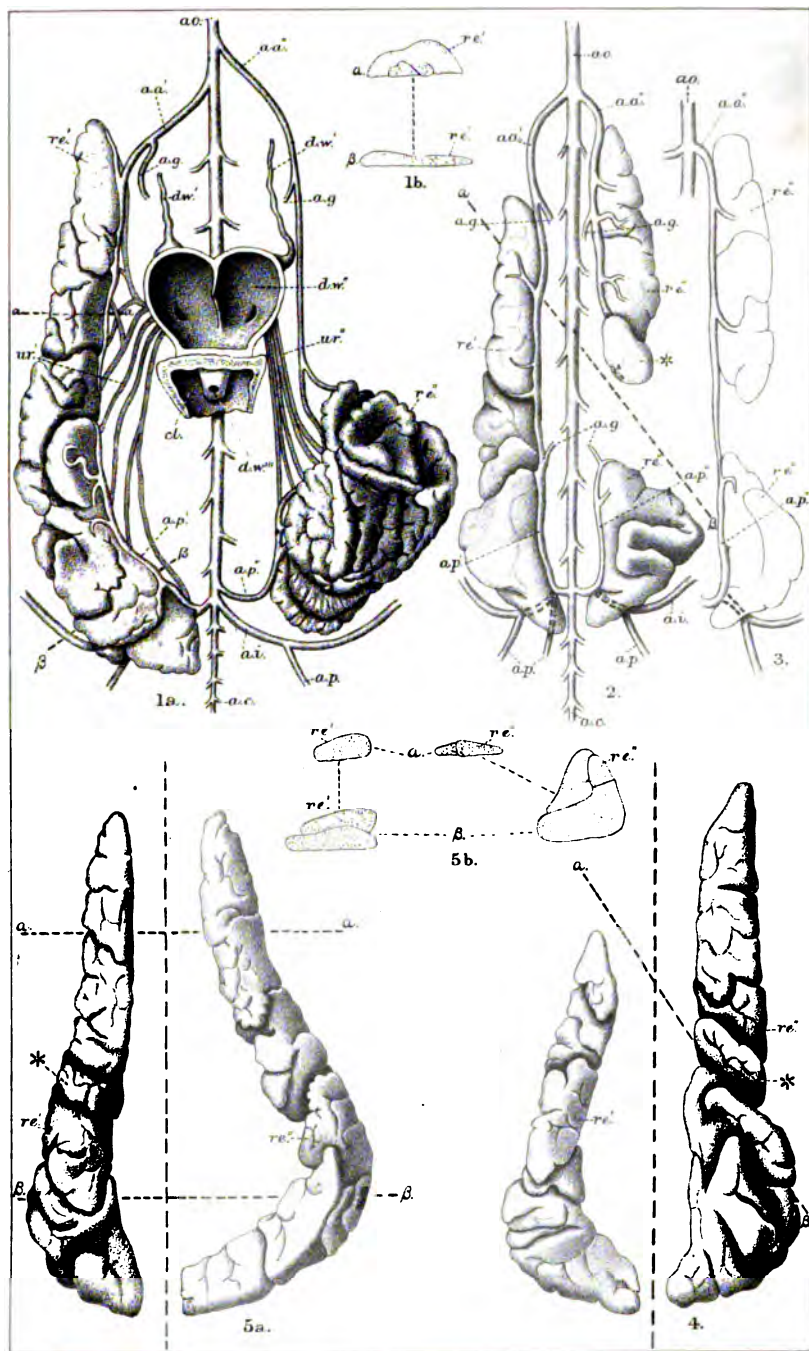
Fig. 6.

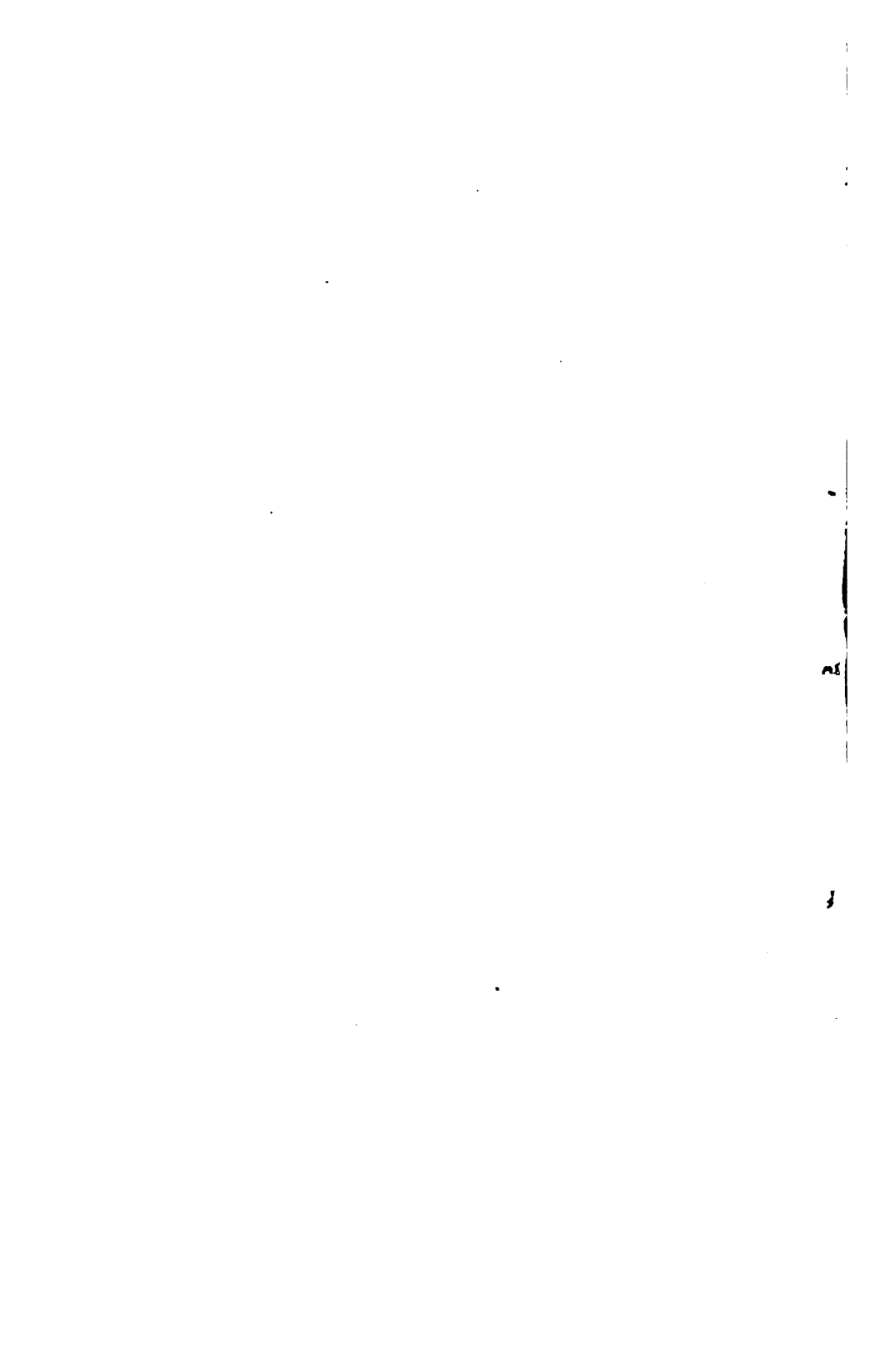


O.H.L. del.

F. H. H. Lith. Edin.

HERMAPHRODITISM IN FROG.





Journal of Anatomy and Physiology.

ACROMEGALY, WITH THE DESCRIPTION OF A SKELETON. By HENRY ALEXIS THOMSON, M.D., F.R.C.S.E., *Surgical Tutor, Royal Infirmary, Edinburgh.*

ALTHOUGH but four years have elapsed since the appearance in the *Revue de Médecine* of M. Pierre Marie's original description of Acromegaly, a number of valuable papers have been published both in Europe and America, in which this newly-christened disease is discussed more or less exhaustively by different writers, and medical literature already supplies an abundant store of clinical cases for the most part described under the name devised by Marie. Many isolated cases also have been discovered by diligent search in previous records, these older cases having been regarded by their observers at the time of publication, in the majority of instances, as of the nature of myxodema. A certain amount of doubt still exists as to the exact combination of symptoms which constitute acromegaly, but M. Marie's description is generally accepted as affording the means of recognising the disease, and of differentiating it from others which simulate it more or less closely. A greater uncertainty, however, exists in relation to the pathology of acromegaly, the disease being comparatively rare, and the opportunities which have occurred of examining the cases after death very few in number. Moreover, the recorded results of such examinations do not agree with one another sufficiently to permit of definite conclusions being drawn as to the etiology of the disease.

The following case is in many respects a valuable addition to those already recorded, and has a somewhat eventful history. During life, the patient, a man of thirty-six, came under Dr Claud Muirhead's care in the Royal Infirmary in 1878, on

account of diabetes mellitus. After death his body was brought to the Dissecting Rooms of the University of Edinburgh, where it was submitted to an exhaustive examination by Dr D. J. Cunningham, then senior Demonstrator of Anatomy, who published a masterly account of the external appearances of the man, and of a number of pathological changes observed in the dissection, in a paper in the *Journal of Anatomy and Physiology* for 1879,¹ under the title of "A Large Subarachnoid Cyst involving the Greater Part of the Parietal Lobe of the Brain." The skeleton was macerated and preserved by Professor Sir William Turner, with the intention of placing it in the Anatomical Museum. On the specimen being referred to the writer for the purpose of being included in the new Catalogue in course of preparation, it was recognised as having belonged to a case of acromegaly. As only two skeletons from similar cases have been hitherto described,—one by A. Broca² and another by Virchow,³—I shall give a full account of the changes observed in this specimen, and I have to record my great indebtedness to Sir William Turner for the valuable help and guidance I have received from him in the course of my work.⁴

For the convenience of those who are not familiar with the more exhaustive papers on acromegaly already published, I shall give a very brief synopsis of the outstanding clinical features of the disease.

Acromegaly may occur at any period of life, but is most frequent in young adults. The onset is insidious, so that the date at which the disease commenced is not always easy to determine with accuracy. The hands and feet become enlarged out of all proportion to the rest of the body, the enlargement being chiefly due to a hypertrophy of the soft parts which commences at the periphery of the extremities. The face becomes elongated and deformed as a result of the increase in size of the bones of the face, more especially of the inferior maxilla, while

¹ Vol. ix. The brain and the enormously distended stomach are preserved in the Anatomical Museum of the University.

² *Archives générales de Médecine*, December 1888.

³ *Berliner Klinische Wochenschrift*, February 1889.

⁴ Sir James Paget, to whom the skull and skeleton had been sent immediately after maceration by Sir Wm. Turner for an opinion, at once pronounced it not to be a case of osteitis deformans.

a forward subluxation of the latter frequently gives an unpleasing aspect to the face. The facial deformity is added to by the prominence of the superciliary ridges and the hypertrophic thickening of the lower lip, tongue, nose, ears, and eyelids. The cranium itself may participate in these hypertrophic changes, and may show an increase in all its dimensions. Headache is frequently complained of, the sight may be impaired or altogether lost, speech is sometimes interfered with, the appetite and thirst are usually exaggerated, and in quite a number of cases diabetes mellitus is found to be present. In women there is usually amenorrhœa. The mental and muscular functions are unimpaired, so that the patient is usually able to continue his occupation, provided this be compatible with the deformities of the hands and face. The progress of the disease is slow, there being but little advance during a period of many years. In advanced cases the muscles become weak, and spinal deformities tend to develop. These usually consist in a kyphosis of the cervico-dorsal region, with sinking of the head between the shoulders; sometimes there is also a scoliosis in the dorso-lumbar region.

The patient ultimately dies from exhaustion, or some intercurrent affection. In every case in which the body has been examined, with one exception,¹ the pituitary body has been found to be very greatly enlarged by a hyperplasia of its normal elements, and a similar hypertrophy affects the ganglionic cords and larger trunks of the sympathetic nervous system.

In some cases the thymus is persistent while the thyroid is said to undergo a process of atrophy.²

The following statements referring to the *Clinical History and Anatomical Examination* of the case of acromegaly here recorded are extracted from Dr Cunningham's paper, to which reference has already been made:—

The patient, a fireman, aged 36, was admitted to the Royal Infirmary in 1878, suffering from diabetes mellitis. Dr Claud Muirhead, under whose care he was placed, described him "as a man of huge frame, with an unpleasing expression and overhanging brows; his hands and feet were enormously large and flat, and his movements clumsy and ungainly. His voice was strong, deep and hoarse.

¹ In the case recorded by Virchow, *Berlin. Klin. Wochenschr.*, Feb. 1889.

² In the cases recorded by Henrot and Godlee, the thyroid was considerably enlarged.

He had no symptoms of paresis or paralysis, and his sight and hearing were unimpaired. His expression was heavy, dull, and stupid, utterly devoid of anything like active intelligence. He was easily irritated, and though sometimes he gave vent to this in a fit of passion, more commonly he exhibited it by hysterical weeping, and in this way his fits of anger invariably terminated. He was entirely uneducated. He died of diabetes mellitus."

When placed in the dissecting rooms the unusual bulk and peculiar appearance of the subject attracted universal attention.

He was a man of a forbidding and low cast of features. His head and thorax were peculiarly large, his limbs were spare, though his hands and feet were enormous. He was 6 ft. 0½ in. in height.

The bones were very large and out of proportion to the muscular development of the subject. The enlargement of each bone was uniform and symmetrical. The bones of the skull were remarkably thick; the superciliary ridges were very pronounced and the frontal air-sinuses of great extent. The pituitary fossa had undergone a great expansion from hypertrophy of the pituitary body.

The muscles were poorly developed and quite out of keeping with the huge frame upon which they had acted.

The brain weighed 50 oz. 6 dr. There was a large subarachnoid cyst involving the greater part of the right parietal lobe of the brain, containing sero-sanguinolent fluid and large enough to hold a hen's egg. The pituitary body was greatly hypertrophied, being four or five times its usual size. It was exceedingly soft and pulpy, and the greatest difficulty was experienced in raising it entire, from the expanded pituitary fossa in which it had rested. It was fully as large as a walnut, and it projected upwards from the expanded fossa so as to press upon the base of the brain. The space bounded behind by the pons Varolii, in front by the frontal lobes, and laterally by the temporo-sphenoidal lobes, was hollowed out into a deep recess for its reception. The enlargement of this area was entirely confined to that part of it which is situated in front of the corpora albicantia. The crura cerebri and pons Varolii had successfully resisted the encroachment of the pituitary body in a backward direction. Owing to the deepening of the space, the corpora albicantia had been brought under the shelter of the pons, and thus they had escaped the results of the pressure.

The frontal lobes, which limit the space in front, had given way before the enlarging pituitary, and in consequence they had sustained a loss of substance.

In the floor of the space the optic commissure had been pushed forwards so as to lie altogether in front of the lamina cinerea. The tuber cinereum and the lamina cinerea were very much thinned, and the former was connected by a large infundibulum with the pituitary body. The optic tract and commissure and the commencement of the optic nerves were rendered perfectly flat by the pressure. Upon each side the optic tract was directly continuous with the tuber cinereum and lamina cinerea. The optic commissure, on the other

hand, was continuous with the anterior part of the lamina cinerea, and together they formed a thin plate of nervous matter which projected forwards so as to overlap the commencement of the median longitudinal fissure. On raising this lamina, a circular aperture, which led into the third ventricle of the brain, was brought into view.

In the sympathetic nervous system there was simply an enlargement of the splanchnic nerves, more marked on the left side. This is to be associated with the hypertrophy of the abdominal viscera.

At the end of this paper, Cunningham laid special stress on the enlargement of the pituitary gland in conjunction with the great bulk of the body, and he regarded the case as the second in which "general progressive hypertrophy" had been associated with such enlargement, the first having been recorded by Henri Henrot, in 1877, in the "*Union Médicale et Scientifique du Nord-Est*."

I shall now give a description of the macerated skeleton.

THE SKELETON.

As has been already stated, the skeleton is that of a male subject, probably from his name a Scotchman, aged 36, and 6 feet in height; the constituent bones are therefore free from the various degenerative changes which may accompany old age, and they do not show any alterations which may be attributed to errors in development.

In taking a general survey of the different parts of the skeleton, what prominently attracts attention is the condition of the skull, although the other bones are not without features worthy of description, in virtue of its peculiar giant-like appearance and facial outlines. On comparing it with other skulls from subjects of similar age and stature, its peculiarity is seen to chiefly depend on the disproportionate increase in the dimensions of the face; the latter is more elongated than broadened, and the elongation is mainly due to an increase in the vertical diameter of the superior and inferior maxillæ. It is further noticed, in profile view, that the facial angle is diminished because of the anterior projection of the chin, a condition which is also to be estimated by looking at the skull from above (the beginning of the sagittal suture being in the centre of the prospective plane), the incisor teeth are then seen in front of the supra-orbital ridges, while the zygomata come into view on either side. Both in full face and profile view the superciliary ridges are large and prominent, and project in front of the

glabella; by overhanging the orbital cavities they impart a frowning and forbidding aspect to the skull as a whole, and cause a deep depression at the fronto-nasal suture. The malar bones project, but there is no evidence of dilatation of the maxillary sinuses, described by A. Broca as characteristic of acromegaly, and as the cause of the prominence of the cheeks during life.

The Dimensions and Characters of the Skull in Detail.—The dimensions of the skull may be gathered from the following measurements, in which I have followed the mode of measuring employed by Sir William Turner in his "Challenger" Report on Human Crania¹:—

Cubic capacity, 1580 c.c.; glabello-occipital length, 200 mm.; basi-bregmatic height, 142 mm.; *vertical index*, 71; minimum frontal diameter, 101 mm.; stephanic diameter, 129 mm.; asterionic diameter, 115 mm.; greatest parieto-squamous breadth, 148 s. mm.; *cephalic index*, 74; horizontal circumference, (a) around superciliary ridges, 567 mm., (b) immediately above the ridges, 561 mm.; frontal longitudinal arc, 147 mm.; parietal longitudinal arc, 138 mm.; occipital longitudinal arc, 133 mm.; total longitudinal arc, 418 mm.; vertical transverse arc, 333 mm.; length of foramen magnum, 33 mm.; basi-nasal length, 106 mm.; basi-alveolar length, 105 mm.; *gnathic index*, 99.1; interzygomatic breadth, 150 mm.; intermalar breadth, 126 mm.; naso-alveolar length, 81 mm.; nasal height, 59 mm.; nasal width, 24 mm.; *nasal index*, 40.7; orbital width, 45 mm.; orbital height, 36 mm.; *orbital index*, 80; palato-maxillary length, 67 mm.; palato-maxillary breadth ap., 70 mm.; *palato-maxillary index*, 104.4. Lower jaw: symphysial height, 46 mm.; coronoid height, 96 mm.; condyloid height, 90 mm.; gonio-symphysial length, 103 mm.; intergonial width, 101 mm.; breadth of ascending ramus, 36 mm.

In the three great dimensions of length, breadth, and height the cranial box considerably exceeds the normal size. It is seldom that a Scottish skull equals 200 mm. in length, 140 mm. in height, and 140 mm. in its greatest breadth, as appears from tables of measurement of Scottish skulls made by Sir William Turner, to which I have had access. The cubic capacity also is

¹ *Zool. Chall. Exp.*, part xxix., 1884.

considerably above the normal, and along with this the horizontal circumference is unusually large. The skull may, therefore, be called megacephalic. The longitudinal arc and the vertical transverse arc are greatly exaggerated, and the transverse dimensions of the face, as shown by the interzygomatic and intermalar breadth are remarkable; but there are no measurements which are more characteristic of acromegaly, as showing an increase in growth, than the naso-alveolar height, the nasal height, and the symphysial height, all of which are greatly exaggerated.

The remarkable elongation of the face in the vertical diameter is perhaps most strikingly demonstrated by taking the diameter from the fronto-nasal suture to the symphysis of the lower jaw, the measurement of which is 148 mm., and comparing it with the same diameter in a series of ten adult male Scotch crania in Sir W. Turner's collection, of which the average measurement is 124.5 mm.

The sagittal and lambdoidal sutures are extensively obliterated. The ridges for muscular attachment are prominent throughout; the median ridge on the tabular part of the occiput, which gives attachment to the ligamentum nuchæ, is represented by a ridge of bone, 6 mm. in height. The external orifice of the external auditory meatus is considerably enlarged, rendering the canal funnel-shaped or conical, with the apex at the membrana tympani.

The orbital cavities are increased in size, their transverse diameter being disproportionately large. The nasal septum shows a deviation to the right, to such a degree as, when clothed with mucous membrane, to practically obliterate the nasal cavity on that side. The upper jaw is markedly elongated in the vertical direction, especially in the interval between the inferior orbital border and the alveolar border. The region of the incisor fossæ is very distinctly concave forwards, giving a somewhat prognathous aspect to the upper jaw. In the region of the canine fossæ there is a certain appearance of lateral compression of the jaw. The suture of articulation between each superior maxilla and its malar bone is obliterated, and the bones are roughened and tuberculated along the line of the obliterated suture. The thickening of the bone in this region contributed, with the overhanging superciliary ridges, to

give that unpleasing expression to the face which was recognised during life. The alveolar margin is massive and spongy. Owing to most of the molar teeth having been shed, the corresponding part of the arch has been to some extent absorbed. The palatal arch is elongated, relatively narrow, and deeply concave; it shows a ridge of recent spongy bone in the middle line along the junction of the constituent plates. The surfaces of the latter are perforated like a sieve by vascular foramina. The glenoid cavity has a capacity little less than that of half a walnut, and in shape it resembles a circular fossa rather than a transverse groove. The enlargement of the cavity has occurred at the expense of its anterior boundary, for, in place of the eminentia articularis, there is a large excavation encroaching on the zygomatic process itself on the left side. These alterations in the glenoid resemble somewhat the common enlargement of joint-sockets met with in arthritis deformans, but with this important difference, that in the latter the articular surfaces become smooth and polished (eburnated), and their margins are the seat of considerable deposit of new bone, commonly spoken of as osteophytes, while in the specimen before us the floor of the cavity is irregular and rough, and there is not a trace of new bone in its immediate neighbourhood.

This expansion of the glenoids is to be associated with the large size of the condyles of the lower jaw, while the disappearance of the eminentia articularis allows the condyles to slide forwards to such a degree that the lower incisors may project beyond those of the upper jaw, causing the forward projection of the former bone and the tendency which it shows to subluxation, which have been observed during life in individuals suffering from acromegaly.¹

The lower jaw is extraordinarily large and massive; its body, which is of great depth, is inclined markedly forwards at the symphysis. The rami show a greater increase in their vertical than in their antero-posterior diameter, and join the body at an angle of $112^{\circ}5$. The lower border is greatly thickened. The alveolar margin is normal, and is filled with healthy teeth. The

¹ See a paper by Mr W. O. Chalk, in which he describes a case of acromegaly under the title of "Partial Dislocation of the Lower Jaw from an Enlarged Tongue," (*Trans. Path. Soc. Lond.*, 1857).

coronoid process ascends to about a third more than its usual height. The condyles show a great increase in their transverse diameter, and are projected forwards and inwards towards the mesial plane of the head.

The foramen magnum is slightly contracted in its antero-posterior diameter, and is circular rather than oval; its margins are surrounded by irregular protuberances of spongy bone, especially around the condyles, and at the sites of attachment of the check ligaments. The cranial bones, as seen in the sawn section by which the calvarium was removed (at the level of the summit of the frontal sinuses), show alterations which are apparently of the nature of a hypertrophy of their normal structure, viz., an external and an internal plate of compact bone with intervening diploë, increased in thickness and in density. The thickness of the bones forming the cranial box varied from 6–12 mm. Herein lies the difference between the “hypertrophied” bone of acromegaly and the “diseased” bone of osteitis deformans (Paget); for in the latter the outer table becomes porous and spongy as a result of inflammatory changes, and the normal distinction between the outer and inner tables and diploë is lost, the entire thickness of the bone consisting of a uniform compact tissue in some parts resembling ivory and in others presenting a chalk-like appearance, which is very characteristic in the macerated skull. Apart from these structural alterations, the well-known tendency of osteitis deformans to be confined to the bones of the cranium, while those of the face are chiefly affected in acromegaly, furnish sufficient data for distinguishing the two diseases in an examination limited to the skull. The section made with the saw in removing the calvarium opened up the frontal sinuses, which were very considerably dilated, that on the left side measuring in the vertical diameter 45 mm., and in the horizontal 35 mm. The infundibulum leading into the middle meatus of the nose could readily be seen on looking down into the sinus. Although the sinuses corresponded in position to the superciliary ridges, the latter did not owe their prominence to the dilatation of the sinuses alone, for the anterior wall which constitutes the ridge was thick and massive, from the formation of new bone in relation to the external table of the skull in this situation.

In the interior of the skull the most striking change is undoubtedly the great enlargement of the pituitary fossa¹ produced by the atrophic pressure of the hypertrophied pituitary body which occupied it during life. The fossa is both deepened and widened, encroaching anteriorly on the olivary process, posteriorly on the dorsum sellæ; the latter is displaced backwards, is as thin as paper; its posterior clinoid processes have completely disappeared, and its superior border is irregularly toothed or serrated. The enlargement of the fossa has rendered the basilar process of the occipital more vertical and much shorter in its antero-posterior diameter. The floor of the fossa itself is pitted and perforated by numerous minute apertures. The increase in depth of the fossa has occurred at the expense of the body of the sphenoid, the latter being only about one-fourth of its normal vertical thickness. The sphenoidal sinus is not enlarged. As a result of the increased size of the pituitary fossa, the optic groove is obliterated and the optic foramina have become flattened from above downwards. The groove for the middle meningeal artery is deep and broad, but this is not so pronounced as is usually seen in osteitis deformans. Lastly, it may be noted that the anterior fossa of the skull is shallower than normal; this is to be accounted for by the large size of the frontal sinuses, and by the encroachment on the cranial cavity of the orbital plates of the frontal.

It may be convenient at this point to refer to the characters of the skull in one of M. Marie's cases of acromegaly, of which an admirable description has been published by M. A. Broca.² It belonged to a female subject, aged 54, and therefore possessed certain characters in which it differed from the one which I have described; in other respects the alterations in the skull were precisely the same in both specimens. The dimensions of the pituitary fossa given by Broca are identical with those here given. The dilatation of the mastoid, sphenoidal, and maxillary sinuses, upon which he lays special stress, do not exist in this

¹ The pituitary fossa measured in its antero-posterior diameter 22.5 mm., in its transverse diameter 21 mm., and in depth, below the plane of the summit of the clinoid processes, 18 mm.

² *Op. cit.*

specimen; the absence of this feature in the latter may probably be due to the fact that it belonged to a subject of 36, while Broca's case was aged 54 years.

Vertebral Column.—There are no evidences of any abnormal curvature having existed during life, from which it may be inferred that the patient succumbed at an earlier stage of the disease than is usually observed, on account of his having diabetes, and therefore he did not suffer from the muscular weakness characteristic of advanced acromegaly, which leads to antero-posterior and lateral curvatures of the spine, provided the patient in his weakened condition maintain the erect posture. The vertebræ are of large size, and exhibit in the dorsal and lumbar regions a series of projecting processes of recent spongy bone along the superior and inferior margins of their bodies, tending to bridge over the interval occupied by the intervertebral disc and corresponding to the anterior common ligament. In arthritis deformans (osteo-arthritis) the characteristic anatomical lesion when it affects the vertebræ, both of man and of animals, is a similar ossification of the anterior ligament, only this is present in a more advanced and extensive form. In a skeleton of acromegaly, recently shown by Virchow to the *Berliner Medizinischer Gesellschaft*, this lesion was also present together with similar bony developments in the extremities; in referring to these changes Virchow pointed out that osteo-arthritis approaches more closely to acromegaly than do osteitis deformans or leontiasis ossea, both of which present certain superficial resemblances to the disease described by Marie. Dr Georges Thibierge, in an able paper in the January number for 1890 of the *Archives générales de Médecine*, entitled "de l'Ostéite Déformante de Paget," describes as characteristic of the latter a partial ossification of the vertebral ligaments or "ankylose externe." In the Museum of the Royal College of Surgeons there is a skeleton¹ of a woman aged 70 with well-marked rickets, in which the margins of some of the bodies of the dorsal and lumbar vertebra are "lipped" from a similar partial ossification of the anterior common ligament. It would appear, therefore, that bony deposits of a diffuse character may occur in acromegaly similar to those which occur in osteitis

¹ Spec. 678A. Injuries and Diseases of Bones.

deformans, osteo-arthritis, and rickets, and constitute only one element in the general trophic disturbance which accompanies these diseases.

Sternum, Ribs, and Costal Cartilages.—The sternum and ribs are of gigantic size; the longest of the latter, *i.e.*, the 7th, measuring 380 mm. along the convexity from end to end. The manubrium sterni appears of great transverse breadth on account of the complete incorporation with it of the ossified cartilages of the first rib on either side. The ensiform and remaining costal cartilages show various degrees of ossification, the process commencing on the outside, so that each cartilage becomes enveloped by a crust of new bone which has a porous structure and reticular arrangement, reminding one of the calcareous deposit seen on objects exposed to the contact of water containing an excess of lime salts. At either end of the cartilage the new bone is fused with the compact shell of its rib and with the sternum respectively. Such an extensive ossification of the cartilages is very unusual at the age of thirty-six; when taken in conjunction with the changes already described in the vertebræ, and with similar bony developments to be noted in the bones of the limbs, one may conclude that there exists in acromegaly a tendency to ossification of ligaments, cartilages, and connective tissues generally, exactly corresponding to what is seen in cases of osteo-arthritis, *viz.*, the development of large masses of bone in the substance of muscles and tendons in parts of the body distant from those affected by the arthritis itself.

The *Bones of the Extremities* present certain characters in common which may be referred to before I describe them individually. They are devoid of those elegant outlines which an anatomist is accustomed to look for in a well-formed skeleton; in appearance they are heavy and clumsy, this being probably due in large measure to the alteration in structure of their superficial layer. The latter, instead of being smooth and almost glistening, as it is in a properly macerated bone, presents a roughened spongy appearance with an infinite number of shallow longitudinal grooves, occupied in the recent state by blood-vessels entering the bone, evincing therefore an unusual degree of vascularity in the periosteum. The latter condition

is to be associated with the evidences of increased activity on the part of the periosteum, to be referred to in detail in the different bones of the extremities.

Upper Extremity.—The clavicles are specially large and bulky. The surface for articulation with the sternum is increased in all its diameters and it is deeply excavated in the shape of a dome, of which the vault is irregularly tuberculated and studded with large vascular openings. The only part capable of coming into contact with the sternum is the margin of this excavation. This deformity of the sterno-clavicular articulations again suggests osteo-arthritis, but is very easily distinguished from the latter by the entire absence of anything like eburnation or other result of joint-movement. Maximum length of clavicle, 180 mm.

In the *scapula* the large size of the glenoid articular surface is very noticeable, and is apparently due to a partial ossification of the glenoid ligament.

The *humerus* shows alterations in its head which correspond to the alterations just alluded to in the glenoid. The muscular ridges, more especially the external supracondyloid, are very prominent. Maximum length of right humerus, 348 mm.; of left, 330.6 mm.

The *radius* and *ulna* of the right side show very remarkable alterations of their superior articular surfaces. The head of the radius is excavated superiorly, and the surface by which it articulates with the ulna is greatly increased in its vertical measurement by a peculiar collar of newly-formed bone overhanging the neck of the radius, while the non-articular aspect is covered with large spongy projections (osteophytes).

The greater sigmoid cavity of the ulna is very much enlarged, its margin having been added to and extended by new bone resembling pumice stone. The articular surface of the cavity is covered with similar irregular rocky tubercles, which must have materially interfered with the flexion and extension movements of the elbow. The periosteal surface of the olecranon is also covered with rocky projections, most noticeable at the insertion of the triceps, while the same formation is seen at the attachment of the brachialis anticus to the coronoid process. These alterations, involving the elbow-joint and the bones in its

vicinity, again present certain resemblances to disease of this joint when affected with osteo-arthritis, and, at the risk of being guilty of repetition, I must again point out that these resemblances are superficial in character although they suggest a degree of affinity between the two diseases. Any one familiar with osteo-arthritis would have little difficulty in recognising the one from the other. Maximum length of right radius, 267 mm.; of left radius, 254 mm.; of right ulna, 282 mm.; of left, 273 mm.

The bones of the *wrist* and *hand* show but little evidence of having belonged to a subject to whose hands the epithet "enormous" had been bestowed by those who saw the man during life; it is, however, generally recognised that the remarkable hypertrophy of the hands and feet in acromegaly is due to an increase in the soft parts, and not to an enlargement of their osseous framework. The metacarpal of the thumb and all the phalanges are, however, actually broader and thicker, and the vicinity of their articular surfaces studded with irregular projections of new bone. The distal ends of the terminal phalanges are especially broad and similarly tuberculated.

Pelvis.—In taking the dimensions of the pelvis of the long bones I have followed the method employed by Sir William Turner in the "Challenger" Reports.¹

Breadth of pelvis, 311 mm.; height of pelvis, 233 mm.; *breadth-height index*, 74·9; between ant. sup. iliac spines, 271 mm.; between post. sup. iliac spines, 90 mm.; between ischial tubera, 166 mm.; greatest diameter of cotyloid cavity, 64 mm. (vert.); vertical diameter of obturator foramen, 60 mm.; transverse diameter of obturator foramen, 41 mm.; *obturator index*, 68·3; subpubic angle, 73°; transverse diameter of brim, 129; conjugate diameter of brim, 97 mm.; *pelvic index*, 75·2; intertuberal diameter, 105 mm.; depth of pubic symphysis, 50 mm.; depth of pelvic cavity, 103 mm.; length of sacrum, 99 mm.; breadth of sacrum, 121 mm.; *sacral index*, 123·2.

From these figures it will be seen that the pelvis is unusually large and bulky. The iliac crests are especially thick and prominent, as are also the other muscular ridges and tubercles. The ileo-pectineal line on the right side is raised into a pro-

¹ *Zool. Chall. Exp.*, part xlvii., 1886.

minent crest. The pelvic cavity answers to the obstetric term *justo-major*, were it not for the projection of the sacral promontory and of the ischial spines. The acetabulum is enlarged by a partial ossification of the cotyloid ligament, while its articulating surface is rough and irregular, and in the vicinity are numerous osteophytes and large vascular canals.

Inferior Extremity—Femur.—The shaft of the femur is especially clumsy in contour, and is unusually straight. The head of the bone shows alterations corresponding to those described in the acetabulum, chiefly shown by an encroachment of the articular surface of the head on the superior and anterior aspect of the neck. There is a partial ossification of the tendon of the obturator externus at its insertion into the digital fossa. On the posterior aspect of the shaft, immediately above the condyles, there is a circumscribed, elevated mass of spongy bone on either side, corresponding in situation to the two heads of origin of the gastrocnemius muscle. The maximum length of the right femur is 479 mm., of the left 487 mm.

The *tibia* and *fibula* on the left side show an extensive incrustation of the periosteal surfaces of their shafts with new bone, minutely perforated for blood-vessels, simulating closely the deposit which results from syphilitic periostitis.

The maximum length of the right tibia (not including spine) is 402 mm.; of the left, 392 mm.; of the right fibula, 392 mm.; of the left, 386.

The bones of the foot are not larger than one would expect to find in a man of 6 feet; those of the tarsus show small osteophytes at the insertions of the tendons. The metatarsals and the phalanges of the great toe are thick and flat, and show tubercles and ridges in the vicinity of their articular surfaces. The terminal phalanx of the hallux is specially deformed; at the proximal extremity the posterior angles incurve anteriorly, so as to form a crescent. Several of the phalanges of the other toes are ankylosed to each other.

In conclusion, the skeletal changes present in acromegaly may be summarised as follows:—

1. Changes peculiar to acromegaly.

- a. Enlargement of the pituitary fossa.

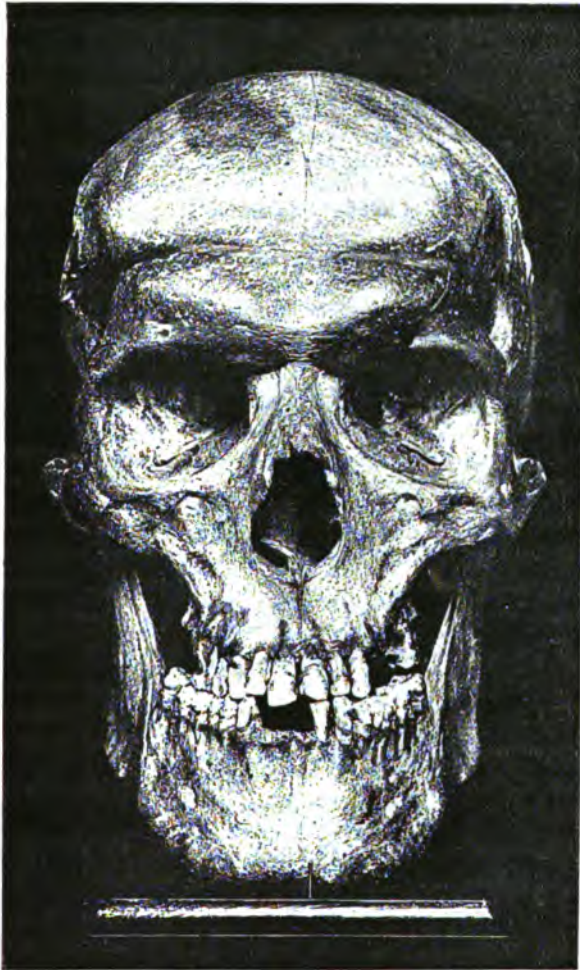
- β. Disproportionate hypertrophy of the bones of the face.

Together with these changes, which, so far as we at present know, do not occur in any other disease, we may include, as constant and fairly characteristic accompaniments, the dilatation of the air-sinuses of the skull; the uniform hypertrophy of certain portions of the skeleton other than the face, viz., those of the cranium, the clavicles, and the metacarpals and phalanges; and finally, the changes in the temporo-maxillary articulation, permitting of a forward subluxation of the lower jaw.

2. Changes which result from a tendency to the formation of new bone both in normal and abnormal situations. These are seen in the mildest form in the great prominence of the ridges for muscular and ligamentous attachment; to a further degree in the ossification of the costal and other cartilages; in the ossification of ligaments (glenoid, cotyloid, vertebral, &c.); in the ossification of tendons, and in the deposit of bone on the articulating surfaces, giving rise to osteophytes, spurious exostoses, anchyloses, alteration of articular surfaces, &c. In these respects the skeleton in acromegaly shows an approach to the changes met with in osteo-arthritis, and in a minor degree to those occurring in osteitis deformans.

The changes in the vertebræ, which result from the long-standing curvatures of the spine usually present in advanced cases of acromegaly, are precisely similar to those met with under other conditions.

The figure on the opposite page is a full-face view of the skull reproduced from a photograph.



INDEX TO THE LITERATURE OF ACROMEGALY.

(For many of the references given here I am indebted to Marie's paper in *Braia*, pt. xlv., 1889, p. 59.)

- Alibert*.—*Précis théorique et pratique des maladies de la peau*, Paris 1832, t. iii. p. 317.
- Aoler*.—County Medical Association, New York, 1833.
- Broca, A.*—*Archives générales de Médecine*, December 1888.
- Brigidi, V.*—*Società medico-fisica-fiorentina*, August 1877.
- Chalk, W. O.*—*Trans. Path. Soc. Lond.*, 1857.
- Cunningham, D. J.*—*Jour. Anat. and Phys.*, vol. ix. 1879. (I have referred to this paper as containing a complete account of a case of Acromegaly, published under the title of a "Large Subarachnoid Cyst, involving the Parietal Lobe of the Brain.")
- Erb*.—*Deutsch. Archiv. f. Klin. Med.*, t. xlii. p. 295.
- Farge*.—*Le Progrès Médical*, 6 Juillet 1889.
- Fraenkel*.—*Deutsch. Med. Wochenschr.*, August 1888.
- Friedreich*.—*Virchow's Archiv.*, Bd. xliii. p. 83, 1868.
- Freund*.—*Sammlung Klin. Vorträge v. R. v. Volkmann*, Leipzig, 1889.
- Fritsche v. Klebs*.—*Klin. u. path. anat. Untersuchungen*, Leipzig, 1884.
- Godlee, Rickman J.*—*Clin. Soc. of London*, April 1888, and *Brit. Med. Jour.*, vol. i., 1888.
- Guinon, Georges*.—*Gazette des Hôpitaux*, 9 Novembre 1889; English abstract in *Illust. Med. News*, January 1890.
- Hadden and Balance*.—*Trans. Clin. Soc. of London*, vol. xviii. and vol. xxi.
- Henrot, Henri*.—*Notes de clinique Médicale*, Reims, 1877; and *Notes de clinique médicale, des lésions anatomiques et de la nature du myxœdème*, Reims, 1882.
- Hutchinson*.—*Archives of Surgery*, October 1889.
- Lanceraux*.—*Anatomie Pathologique*, t. iii. 1^{re} partie, p. 29.
- Lombroso, Ces.*—*Giornale ital. delle malattie veneree etc.*, 1868; translation by Fraenkel in *Virchow's Archiv*, t. xli. p. 255; republished in *Annali Universali di Medicina*, t. 227, p. 505.
- Marie, Pierre*.—*Revue de Médecine*, Avril 1886; *Nouvelle Iconographie Photographique de la Salpêtrière*; *Le Progrès Médical*, Mars 1889; *Brain*, part xlv. 1889, p. 59.
- Minkowski, O.*—*Berliner Klinische Wochenschrift*, Mai 1887.
- Saucerotte*.—*Mélanges de Chirurgie*, 1^{re} partie, 1801, p. 407.
- Saundby*.—*Illustr. Med. News*, March 1889; and *Brit. Med. Jour.*, vol. ii., 1888, and vol. i., 1889.
- Simon*.—*Brit. Med. Jour.*, October 1888.
- Taruffi, Ces.*—*Annali Universali di Medicina*, 1879, t. 247 and 249.
- Tresilian, Fred.*—*Brit. Med. Jour.*, March 1888.
- Verga, A.*—*Rediconti del Reale Istituto di Scienze e Lettere*; *Adunanza del 28 Aprile 1864*.
- Verstraeten*, *Revue de Médecine*, Mai 1889.
- Virchow*.—*Deutsch. Med. Wochenschr.*, Feb. 1889; translation in *Illust. Med. News*, March 1889.
- Wadsworth*.—*Boston Med. and Surg. Jour.*, January 1885.
- Wilks*.—*Trans. Clin. Soc. of London*, April 1888, and *Brit. Med. Jour.*, i., 1888.

THE HISTOLOGY OF THE SKIN OF THE ELEPHANT.

By FRED SMITH, M.R.C.V.S., F.I.C., *Professor, Army Veterinary School, Aldershot.* (PLATE XVIII.)

In dealing with the minute anatomy of the skin of the Elephant, I have found it necessary to divide it into certain parts for clearness of description. The skin of the trunk, ears, body, and limbs will therefore be separately described, for, as we shall see, they in some important respects differ widely from each other.

Trunk.—The skin of this region will be divided into that clothing the inferior or touch extremity of the trunk, and the body or main portion of that organ. It is not to be wondered at that the skin of this part should be of varying character, when we remember the remarkable prehensile and tactile power possessed by the lower extremity of the trunk.

The corium of the touch extremity is composed of white fibrous and yellow elastic tissue interlacing to form networks, and between which are found a varying quantity of muscular tissue of the striped variety. The meshes formed by the fibrous and elastic tissues are larger at the deeper than at the superficial portions of the skin, for here they run closer together to form the papillary portion of the corium. The corium rests upon the muscular tissue of the trunk, and fibres from this part pass outwards through the corium and reach to nearly the most superficial parts of the layer. The mean thickness of the corium is $\frac{1}{8}$ of an inch. The papillæ formed are remarkable for their extreme length—they are long finger-like processes, lying close together, and passing directly outwards to reach the superficial layers of the epidermis; the fibrous tissue of which they are composed takes rather a wavy direction, and the papilla itself ends in an obtuse point within a short distance of the surface of the skin (fig. 1). As a rule, the papillæ are single, but sometimes they are multiple, viz., two or three arising from one base. The length of these papillæ will be found to be from $\frac{1}{10}$ to $\frac{1}{8}$ of an inch, and their width at the base from $\frac{1}{100}$ to $\frac{1}{50}$ of an inch. Blood-vessels, nerves, and even muscular fibre may be seen

running up quite close to the base of the papillæ, but I have never distinctly traced any of these into the substance of this part, though, of course, the papillæ are composed largely of nervous material.¹ Their undoubted use is to supply that delicate and perfect sense of touch possessed by this animal, and to this purpose the papillæ are in connection with certain nerve-endings which are found scattered throughout the corium of the touch extremity.

These nerve-endings are irregularly oval in outline, and are composed of concentric layers like an onion, the central portion or nucleus being solid and granular (figs. 1 and 2). They are of great size, varying from $\frac{1}{80}$ to $\frac{1}{50}$ of an inch in length, and $\frac{1}{40}$ to $\frac{1}{160}$ in width; the central portion or nucleus being $\frac{1}{800}$ to $\frac{1}{700}$ of an inch in diameter. These nerve-endings are scattered throughout the superficial portions of the corium, generally beneath the papillæ, and are either single or exist in small groups of two's and three's. I have only once been able to trace a blood-vessel into them, and it has not been possible to more clearly define their arrangement. This is owing to the tissue being stale. The trunk is the only part of the elephant's skin where we find special nerve-endings. I have not been able to clearly define the area over which they extend, but I am certain that they exist in larger numbers on the touch extremity than elsewhere.

The blood-vessels in the corium are numerous and large, but have no special distribution.

In no part of the skin of the Elephant can sebaceous or sudoriferous glands be found, and the trunk is no exception to this rule.

The epidermis covering the touch extremity of the trunk is enormously thick, and arranged, as in other animals, in layers of cells fitted into each other with the most perfect regularity. These cells take, of course, the general contour of the skin at this part. In bold masses they sweep up the side of the long papillæ, forming a large convex cap for the summit, and immediately descend on the opposite side of the prolongation. The deeper cells contain a large amount of pigment. The

¹ The reason I have not been able to absolutely demonstrate the nerves by staining is on account of working with material six years old.

epidermis, which is found to cap the papillary process of the corium, is sometimes arranged in rather a singular manner I cannot better describe it than by saying that at the top of the papilla is a space containing a number of cells; in my notes I have spoken of it as a nest of cells, and perhaps this is the best term to use for it; these nests grow outwards, so that some are found in the middle of the epidermis and some on its surface. Surrounding the nests are the epidermal cells, many of them being spindle-shaped. The cells occupying the nests are generally round or oval, and somewhat resemble cartilage cells, the nest itself being formed either of a fibrous-looking material, or by means of the spindle-cells previously alluded to. Some large spindle-shaped or oval cells may also be found in groups (not arranged distinctly in nests) scattered through the substance of the epidermis, which in some cases are strikingly like cartilage cells, and possess a large oval or round nucleus. This arrangement of cell "nests" exists in other parts of the body, particularly in the skin above the nail, and in the nail itself.

The general arrangement of the pigment in the epidermis is to cause it to present under a low power an appearance of black streaks extending from the corium to the surface of the skin, separated by means of cells which are comparatively free from pigment.

The thickness of the epidermis is from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch.

In the upper part of the Trunk the long papillæ have disappeared, and their place is taken by what I will have to describe as compound papillæ, viz., there is a large primary papilla, and from this several smaller secondary ones grow (fig. 3). Muscular tissue is still largely present in the part, and the same special nerve-endings are to be found; hairs, however, are to be seen here, which are almost absent from the touch extremity of the organ.

The Skin of the Ear is remarkable for its extreme vascularity, and the comparative thinness of the corium and epidermis. The papillary layer of the corium consists of primary and secondary papillæ, the primary being somewhat cone-shaped, and the secondary varying in number from two to nine. The rete Malpighii is thickest in the centre of the primary papillæ, and

diminishes to a mere streak at the extremities of it. Hairs are found in this skin.

The Skin of the Body.—The corium is of considerable thickness, about $\frac{1}{8}$ of an inch; it is composed wholly of white fibrous and a little yellow elastic tissue, interlacing in all directions, and forming large spaces below and small ones above. The papillæ are of the compound order, viz., a large primary papilla, which is an archway-like projection $\frac{1}{6}$ of an inch at its base, and projecting upwards for the same distance into the epidermis, from the upper surface of this archway the secondary papillæ are given off, being from eleven to fifteen in number, and having a length of $\frac{1}{20}$ to $\frac{1}{30}$ of an inch, and a base of from $\frac{1}{30}$ to $\frac{1}{40}$ of an inch.

The nerves of the corium are numerous, giving off loops to the primary papillæ, which in turn give off branches to the secondary papillæ; occasionally a main trunk enters a primary papilla, and breaks up into secondary branches. There is no regularity in their distribution, and I do not think that every secondary papilla has a nerve.

There is not a trace of glandular structure in this skin.

The epidermis of the skin of the body is arranged much as elsewhere, the deepest cells being very large, nucleated, and containing much pigment. Again, we notice the extreme regularity of the cells, both large and small, comprising this layer. The general direction of the cells corresponds to the outline of the papillæ; at the depression where two papillæ meet the amount of pigment is very great, and as this is continued outwards through the layer, it gives the part a laminated appearance. The epidermis is about the $\frac{1}{80}$ of an inch in thickness.

The skin of the limbs was examined particularly at the margin of the nails. The corium is from $\frac{3}{8}$ to $\frac{1}{2}$ of an inch in thickness, and is remarkably vascular; its papillæ are both compound and single, the latter predominating close to the nail, and being there in shape much like those found on the touch extremity of the trunk, with the exception that they all appear to be vascular papillæ, and large convoluted vessels run into them quite close to the termination of the epidermis. The convoluted vessels strikingly reminded me of what a sweat gland would be if elongated; in fact, I thought at first these must be glands, but

I feel convinced that they are blood-vessels. They are the $\frac{1}{1000}$ of an inch in diameter, and the plexus is $\frac{1}{12}$ of an inch in length.

I could not determine any special nerve-endings at this part. The epidermis on the skin above the nails is very thick, and resembles that found on the touch extremity of the trunk; as we get nearer to the nail the appearance is more like horn; in fact, it is impossible under the microscope to say exactly where the skin ends and the horn begins. The large vascular papillæ, with the convoluted vessels mentioned above, run only into the epidermis a little above the nail, but not into the wall of the nail itself. The papillæ from the corium immediately above the nail extend into the epidermis and nail wall for a distance of from $\frac{1}{8}$ to $\frac{1}{16}$ of an inch. I observed in the epidermis of this part the same cell collection, or cell "nests," found on the touch extremity of the trunk.

The *Hairs* in the skin of the Elephant may broadly be divided into two classes,—hairs and bristles. The former are much finer than the latter, which are coarse, powerful, and of great length. The microscopical differences are also very great; the hairs are mainly solid in their structure, whereas the bristles are perforated for a considerable length by foramina. I am not prepared to say whether a hair ever grows into a bristle, but I am confident that in the animal's skin we find these two distinct classes. Before describing the appearance of a hair, it will be necessary to look at the sacs in which it is enclosed.

On making a section of the skin of the trunk, we are struck by the appearance of certain greyish, pear-shaped bodies, of such remarkable size that they are readily seen by the naked eye; in length they are $\frac{3}{8}$ of an inch, and in their greatest diameter $\frac{3}{16}$ of an inch (fig. 7). These bodies are the hair follicles, or perhaps more correctly the bristle follicles, for the hairs are contained in a smaller sac, which never reaches such a size as that of the bristles. The sheath of the bristle follicle is greyish in colour and very tough, and may microscopically be readily separated into an external and internal sheath. The internal sheath is smaller than the external; in structure it is cellular and fibrous, the two appearing to alternate; in a longitudinal section the one layer is seen above the other; in transverse section the

fibrous layer is seen to throw out projections towards the external root-sheath, and to be arranged around it in a somewhat radiating manner; between the limbs thus thrown out we see the cellular structure, which is almost exactly like cartilage. Externally this follicular sheath is in contact with the external sheath of the follicle. The two are intimately blended, but by exercising a little pressure on the section, it will be seen that they fit into one another by means of the processes from the internal follicular sheath.

The papilla of the hair or bristle rests on the internal sheath of the follicle; this sheath is here comparatively narrow, and its structure is principally fibrous, containing many connective-tissue corpuscles. The internal sheath of the hair-follicle stains quite differently with picro-carminé from the external sheath, taking on a much lighter carminé tint. The vascularity of the internal sheath of the follicle is also remarkable, and it is highly endowed with nerves.

The external sheath of the follicle is much more fibrous and larger than the internal sheath, and consists of bundles of fibres interlacing in all directions. It stains of a deep red with picro-carminé. Though with the naked eye it is easy to determine the sharp outline of this sheath from the surrounding corium, yet under the microscope it is rather difficult to say where one ends or the other begins.

Surrounding the hair or bristle we have the internal root-sheath, and outside this the external root-sheath, which in turn lies in contact with the internal sheath of the follicle.

The internal root-sheath is a vitreous layer enveloping the shaft of the hair; in small hairs it is the $\frac{1}{300}$ of an inch in diameter, whilst in the bristle it is from $\frac{1}{300}$ to $\frac{1}{200}$ of an inch in diameter. In transverse sections it is seen to be composed of an imbricated layer of glassy cells, those next the hair being the smallest, whilst those outside them are large and irregular in outline, and lie over each other. In longitudinal sections the cells appear to take a more definite direction, but are just as structureless and glassy in appearance. This sheath passes under the hair, but terminates at the papilla; it is quite impossible to stain it.

The external root-sheath does not pass down to the bottom

of the hair; it is much narrower below than above, where it enlarges considerably. In structure it is cellular, the cells being large, oval, and nucleated. Those cells next to the vitreous layer are arranged diagonally to the hair, whilst the cells nearest to the internal sheath of the follicle are horizontal. This layer stains orange-red with picro-carmin, presenting a marked contrast to the vitreous layer. I have often observed a dark irregularly broken line separating the internal from the external root-sheath. The outer zone of the external root-sheath is always more opaque than any other part. The diameter of the external root-sheath varies from $\frac{1}{300}$ to $\frac{1}{300}$ of an inch.

The papilla of the hair or bristle is formed by the internal sheath of the follicle; it is largely cellular in structure, and I believe that prolongations from it pass up into the foramina found in the bristles, but on this point I am not positive.

The hairs and bristles are black in colour; both may be found on the body, but I think the bristles are more plentiful on the trunk and tail than elsewhere. I recognise the bristles by their being much coarser than the hairs, and by possessing a much larger sac; this latter reaches its full development in the trunk.

Both hairs and bristles penetrate the skin obliquely, and run into it for a distance varying between $\frac{1}{4}$ to $\frac{1}{2}$ an inch; they gradually decrease in thickness as they pass outwards; the bristles are 3 or 4 inches long, the hairs about half this length.¹ The bristles on the tail (which I have not had an opportunity of examining microscopically) are of immense thickness and length.

If a longitudinal section of a bristle be made, and that portion examined which is outside the skin, a number of dark lines of pigment may be seen running the length of the bristle, separated by a substance much lighter in colour. These streaks indicate the remains of the canals or foramina. If that portion of the bristle which is within the skin be examined in longitudinal sections, the canals are there seen not as perfectly clear spaces, but much lighter in colour than the parts on either side of them. If we take a bristle and make transverse sections of it from the

¹ I am here only referring to the specimens in my possession; it is most likely that the length of these appendages varies considerably according to climate and season.

root upwards, it will be found that the foramina do not run the length of the bristle, but cease about on a level with the epidermis. The foramina are twenty or thirty in number, and oval or round in outline (fig. 5). Surrounding these openings we have the cells of the hair arranged in a concentric manner, and the appearance presented under a high power is strikingly like bone, only that the laminæ formed by the hair cells are very small. The cells forming the hair or bristle substance are of the pavement variety, each cell containing a large black nucleus; around the foramina the cells become flattened. The canals in the hair are not empty, but contain highly refractile cells like the internal root-sheath; on section many of these fall out and thus leave the part perfectly clear.

The hairs are solid for the greater part of their length, and many of them may be solid throughout, but there can be no doubt that I have detected foramina at the deepest part of many hairs just above the papillæ (fig. 6). They do not run up the shaft for any great distance, nor have I seen them in all specimens examined, but there can be no doubt that many of the hairs on all parts of the body contain foramina filled with vitreous-looking material.

The diameter of the bristles is about the $\frac{3}{10}$ to the $\frac{1}{4}$ of an inch, the measurement being made close to the papilla; as they pass higher up in the skin they get narrower. The foramina are from $\frac{1}{1000}$ to $\frac{1}{300}$ of an inch in diameter. The hairs are from $\frac{1}{160}$ to $\frac{1}{120}$ of an inch in diameter; some on the body are double this size.

The Nails of the Elephant.—In describing these, I am compelled to use the nomenclature adopted in describing the hoof of the Horse. Thus the nail has a wall and a sole; the wall is crescentic in shape above and at this part is very thin; it gradually increases in thickness to about $\frac{3}{8}$ of an inch, and maintains this all the way down. On the internal surface of the wall are a number of horny laminæ or leaves, which fit in between a corresponding number of sensitive laminæ, which are found on the outside of the bone of the nail (fig. 8). The horny laminæ, unlike those of the Horse, extend for a short distance on to the horny sole. The horny laminæ do not reach within an inch of the top of the wall, but where they exist are as well developed as in the Horse. The sole of the nail is very thick—

about $1\frac{1}{4}$ inch. On the upper part of the sole, next to the sensitive foot, are a large number of foramina of great size to accommodate long villi growing from the sensitive sole. The width of the nail, from corner to corner, is 5 inches, and its height at the centre $2\frac{1}{2}$ inches.

A transverse section of the wall, including the laminæ, when viewed microscopically, is found to differ, depending upon whether the section is from the centre or sides of the nail, or whether we are studying the wall or the leaves; the latter are cone-shaped, and possess certain lateral irregularities corresponding to the lateral laminæ of the Horse. The laminæ terminate either in an obtuse point or in two or more projections. In some places it may be seen that the laminæ are bridged across, and thus a canal or foramen formed. This is particularly the case with the corners of the nail rather than its central portion. Here we find the laminæ more obliquely placed, and lie closer together, and they are bridged across or connected by a tissue which is undoubtedly horn, and yet in some of its characteristics is wholly unlike any other horn with which I am acquainted. The bridging across of the laminæ leads to the formation of many foramina, and I am satisfied that I have found that those next to the sensitive tissue often contain a blood-vessel.

The union of the horny laminæ with the wall of the nail is peculiar. The laminæ appear to pass into the wall and then become fibrous in appearance, the fibres being remarkably wavy, and, curving up and down both to the right and left unite with similar fibres passing from the neighbouring laminæ. So far as the centre of the wall is concerned we observe nothing else of importance in connection with this structure, but at the lateral edges of the nail we find that the fibres of the horny laminæ enclose long strips of tissue, penetrated by some large canals, and that around these canals we have fibres disposed in a circular manner, and an appearance of lacunæ produced by the pigment existing in the horn cells. This structure, which I have previously mentioned above, is so singular that it can only be understood by the aid of the drawing (fig. 9). The contents of the canals are cellular, though one, as I noted above, often contains a blood-vessel. The cells which fill the others are

large, round or oval, and readily stain with carmine, presenting a great contrast to the surrounding horny tissue, which is stained yellow by picric acid.

On examining with the naked eye a section of the wall which has been stained with picro-carmine, we find that the horny laminae take on a decidedly carmine tint, forming a marked contrast to the yellow wall.

I am quite certain that some of the large canals just spoken of contain a blood-vessel (it is generally contained in that canal nearest to the sensitive laminae), but I am not clear on the point as to whether nerve-tissue is found in them, though on three occasions I have seen a body in the canal closely resembling the nerve-endings found in the trunk.

The structure of the wall proper is simple; it consists of foramina and inter-foraminal tissue. The latter is composed of epithelial cells, each one containing a small nucleus; towards the canals the cells become compressed and elongated, constituting the rings or laminae we see surrounding the canals; the latter are oval or elongated; the largest ones are found nearest to the sensitive structures of the foot, those situated anteriorly are narrower but longer. They take the carmine dye readily, whilst the surrounding tissue is stained yellow; the canals are filled with elongated cells, and it is these which, taking the carmine dye, give the colour to the part (fig. 10).

The structure of the sole is very much like that of the wall, only that here the canals nearest to the sensitive part are of considerable size, to accommodate long sensitive papillae which pass down into the depth of the horny tissue for about half an inch; below this the canals get much smaller, and the structure closely resembles the wall. We must for a moment amplify the description given of the upper part of the sole. Here we find well-marked horny rings surrounding the canals, and the cells of these laminae contain a nucleus closely resembling lacunae; so much does this appearance resemble bone tissue that I think it possible for even an experienced microscopist to fall into an error respecting the structure if examining an unlabelled slide. The contents of these canals are stained carmine.

The points of interest in the skin of the Elephant I believe to be these—

1. The long finger-like papillæ on the tip of the trunk placed in connection with special nerve-endings, and no doubt conveying that exquisite sensibility which the animal is known to possess in this part.
2. The compound primary and secondary papillæ in the skin.
3. The absence of anything approaching glandular structure.
4. The canal system which exists in all bristles, and in a modified degree in most hairs.
5. The arrangement of the horny and sensitive laminæ at the corners of the nail, and the presence of a blood-vessel in true horny tissue.

From careful inquiries made of competent persons, I believe that the skin of the Elephant has not been previously described.

EXPLANATION OF PLATE XVIII.

Fig. 1. Section of skin on the touch extremity of the trunk. *a*, the long finger-like papillæ; *b*, nerve-endings; *c*, blood-vessel; *d*, muscular tissue.

Fig. 2. Nerve-endings in the trunk. *a*, single; *b*, multiple.

Fig. 3. Primary and compound papillæ. *a*, primary; *b*, compound.

Fig. 4. Section of bristle from the trunk with enveloping sacs.

Fig. 5. The bristle, with inner and outer root-sheaths more highly magnified. In the drawing the inner root-sheath does not possess the vitreous appearance shown in the specimen.

Fig. 6. *a*, Hair and sheaths from the body—the position of the canals is indicated by the collection of pigment cells; *b*, a thinner section of hair showing the position, or rather remains, of canal structure.

Fig. 7. Position of the bristle and sacs in the skin of the upper part of the trunk.

Fig. 8. Section of wall of nail showing horny laminæ. The proportion between the length of the laminæ and width of the wall is not preserved in the drawing.

Fig. 9. Section of wall taken from the corner of the nail, showing *a*, the horny tissue between the laminæ; *b*, the laminæ; *c*, the remarkably wavy course taken by the fibres of the laminæ; *d*, the foramina in the wall of the nail.

Fig. 10. Longitudinal section of the wall showing the canals.

Fig. 11. Convolted vessels found in the papillæ of the skin above the nail. They run for a considerable distance into the epidermis.

Fig. 12. Portion of epidermis from the surface of the skin above the nail. *a* is the surface of the skin. The epidermis is crowded with cell-nests.

A CONTRIBUTION TO THE PATHOLOGY OF RETRO-BULBAR NEURITIS. BY WILLIAM ALDREN TURNER, M.B. (Edin.), M.R.C.P. (Lond.).

Some Clinical Points.—That a defect in vision may occur in persons of intemperate habits and in those who habitually smoke the stronger forms of tobacco, has long been known. Examination of the defect shows that it is of the nature of a central scotoma. After some premonitory cloudiness of vision, the deficiency indicates itself by an inability to distinguish colours, mainly red and green; in many cases this goes on to true visual defect, so that the person is unable to see objects placed so that the rays from them fall on the central part of the fundus oculi. The appearance observed on ophthalmoscopic examination is usually some blanching of the temporal sides of the optic discs. This central scotoma is the typical form of toxic amblyopia, being caused by alcohol more especially in those who habitually soak, than in those who only at times indulge too freely, and by tobacco when the use of its stronger forms is carried to excess. The evidence that alcohol alone can produce the condition is not yet conclusive, but it appears probable that central scotoma does not occur without the association of tobacco.¹ A similar condition has also been observed in diabetes mellitus and in poisoning by bisulphide of carbon, but whether it is due to the toxic effect of the sugar or of the bisulphide acting alone is not known, as in the reported cases the patients have at the same time been heavy smokers. But there is another form of scotoma, towards the causation of which no toxic influence can be assigned. This variety is distinguished from the central toxic form by the fact that the scotoma is not limited to the papillo-macular region, but extends to the nasal side of the fixation point, and in addition there is usually some peripheral restriction of the visual field. This form usually affects only one eye, and is as common in women as in men.²

¹ For much evidence on this point vide *Ophthalm. Soc. Trans.*, vol. vii.

² Berry, *Diseases of the Eye*, p. 308.

Pathology.—Until a few years ago the pathology of central scotoma remained unknown. It is probable that in those cases in which recovery takes place, some functional disturbance of nerve elements only has occurred; but when the condition has been progressive and the nerves subjected to *post-mortem* examination, a definite and well-marked change has been observed.

Magnan¹ appears to have been the first to have examined the optic nerves in a case of general paralysis of alcoholic origin in which amblyopia had been a symptom. He described a "diffuse interstitial neuritis" of both optic nerves, but of unequal degree.

Samelsohn² was the first to describe its true pathology in cases of combined alcoholic and tobacco poisoning. He considered the condition to be a primary inflammation of the strand of fibres supplying the macula lutea, which tract occupied a definite position in the optic nerve. Its position was figured by him and has been corroborated by subsequent observers. The change further was an interstitial one causing descending pressure-atrophy, and its point of commencement was in the optic canal, which was the point of the greatest intensity of the inflammation.

Messrs Nettleship and Edmunds³ described the appearances in the optic nerve from a combined case of diabetes mellitus and tobacco poisoning. In their paper is figured a specimen very similar to that which I am about to describe. It shows well an increase of nuclei with thickening of the trabeculae, and the walls of the blood-vessels with secondary atrophy of the nerve-fibres. They also describe the wedge-shaped area on the temporal aspect of the nerve. Uhthoff⁴ records a series of seven cases with an account of a careful examination of the optic nerve and tract, and his conclusions may be briefly stated as follows:—There is a degeneration of the outer (temporal) half of the optic nerve, conical in form, with the apex pointing towards the central vessels; 6–7 mm. behind the globe, the area is half-moon shaped; 7–8 mm. further back the degenerated area is oval; at the optic foramen it is centrally placed; behind this the degeneration is less marked, but can be readily traced through the optic chiasme and optic tract, where it occupies a central position. Sachs⁵ has recently described a similar condition; in his preparations the degenerated area occupies a similar position to that previously recorded; further, the intensity of the degeneration was greatest in the middle of the optic canal, and all along the affected tract the

¹ Magnan, "De l'alcoolisme," Paris, 1874, page 195 of Dr Greenfield's translation.

² Samelsohn, *Von Graefe's Archiv*, vol. xxviii. pt. i. p. 1; also *Centralblatt f. d. Med. Wissensch.*, Berlin 1880, xviii. p. 418.

³ Nettleship and Edmunds, *Trans. Ophth. Soc.*, vol. i. p. 124.

⁴ Uhthoff, *Von Graefe's Archiv*, vol. xxxii. pt. iv. p. 95.

⁵ Sachs, *Archiv für Augenheilk.*, 1887, vol. xviii. pt. i. s. 21, also *Ophthal. Rev.*, vol. vii. p. 105.

degree of atrophy was greater near the middle of the degenerated area than at the periphery; the change was an interstitial one, with secondary disappearance of the nerve-fibres.

*Description of the Preparations.*¹—The specimens here described are the orbital portions of both optic nerves; and, following the method of previous observers, this portion of the nerve is conveniently divided into two parts, that which is proximal to and that which is distal to the entrance of the central artery of the nerve. The subject from which the nerves were taken was a woman of about thirty years of age, of dissolute habits. The influence of tobacco in causing the condition here cannot be definitely stated, but it is probable that she indulged in smoking to some extent. The *post-mortem* examination revealed signs of chronic alcoholism in the stomach and liver, but there was no evidence of alcoholic neuritis affecting any of the other peripheral nerves. It was not possible to obtain an account of the examination of the eyes made during life.

1. *Hæmatoxylin-Stained Preparations*² (fig. 1).—A localised proliferation of the corpuscles, both of the connective tissue of the trabeculæ and of the nerve-fibres, is at once apparent, occupying a definite and well-marked region in the transverse section of the nerve. In the portions of the nerve distal to the entrance of the central vessels, this area forms a fairly regular wedge-shaped tract, extending from under the nerve sheath on the temporal side, where the base of the wedge is situated, to the central vessels where the apex obtains; as one passes upwards towards the hilum, where the vessels enter, the apex is observed extending across towards the nasal side, and in the portions of the nerve proximal to the entrance of the vessels the area is found to have extended across to under the nerve sheath on the nasal side of the nerve. It still preserves its cone-shaped appearance, but the base has broadened out and occupies more of the periphery. The proliferation of corpuscles

¹ The preparations described here were obtained by the author when working in the laboratory of the Pathological Institute, Berlin, under Prof. Virchow.

² The nerves were hardened in Müller's fluid for ten days in an incubator; subsequently they were imbedded in celloidin by the usual methods. Some were stained in a weak solution of hæmatoxylin for twenty-four hours, and others in a $\frac{2}{3}$ per cent. solution of Weigert's hæmatoxylin; the latter were differentiated by the borax-ferridcyanide solution.

has to a great extent obscured the bundles of nerve-fibres and led to an increase of the connective tissue of the trabeculæ. This is most marked at the periphery of the temporal side, where the bundles of nerve-fibres are showing the greatest signs of disintegration. The nerve upon this side is flattened, and the inner layer of the nerve-sheath is infiltrated with leucocytes.

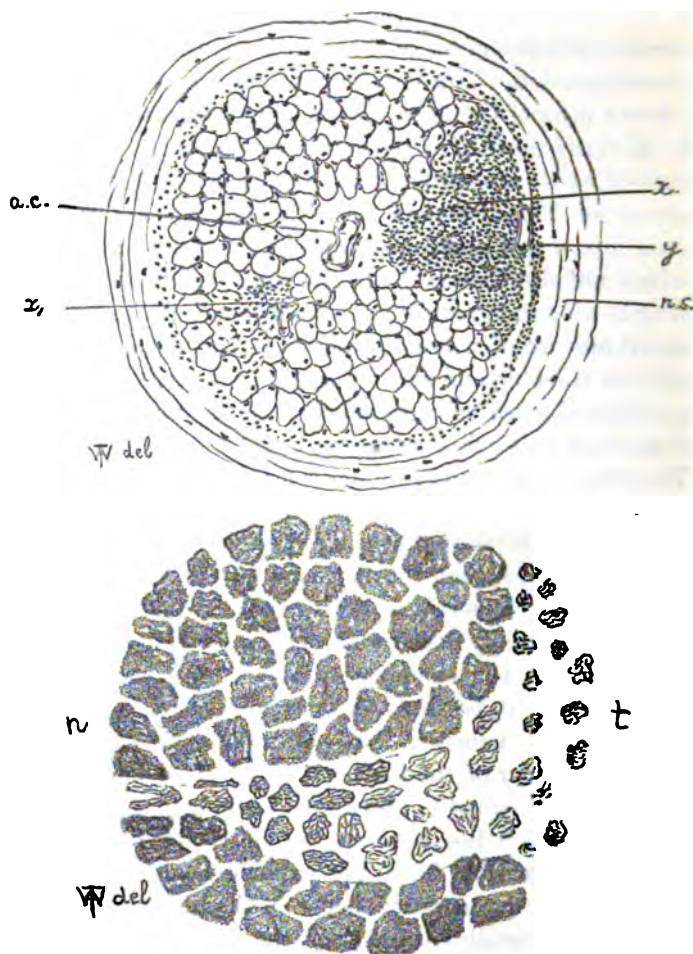
2. *Weigert-Stained Preparations.*—In these the changes described above are verified and shown more distinctly. Under a power of 250 diameters the axis cylinders are seen to be broken up, many showing a varicose appearance; globules of myeline are also observed. In the whole series the part of the nerve showing the greatest increase of connective tissue and the greatest amount of nerve destruction is that situated under the sheath on the temporal side. In no part is there an area showing entire absence of nerve-fibres; in the most degenerated portion some axis cylinders are noticed.

The changes here observed agree for the most part with those previously recorded; it is to be regretted that the portion of nerve situated in the optic canal was not preserved. Sachs, however, mentions that the degenerated fibres do not occupy the centre of the nerve as described by Samelsohn, but are situated eccentrically downwards and outwards. As a report of the history and the examination of the eyes in the present instance could not be obtained, it is not possible to assign the true cause for the neuritis. The patient's habits would lead one to argue in favour of the toxic affection. This being the case the degenerated strand of fibres would supply that region of the fundus oculi which lies between the optic olige and the outer margin of the macula lutea, the papillo-macular region. The area of greatest degeneration being on the temporal side of the nerve, causes usually atrophy of the temporal side of the papilla; and if, on removal of the toxic agents, recovery from the amblyopia occurs, it starts from the nasal side where there is least degeneration of nerve-fibres, and this has been known to occur even where there was progressive atrophy of the papilla.¹

The change, then, produced by alcohol and tobacco on the optic nerve is an interstitial neuritis leading to inflammation and secondary degeneration of the nerve-fibres; and the neuritis

¹ *Ophth. Review*, loc. supra cit.

has been shown to attack the strand of fibres which supply the papillo-macular region of the fundus oculi.



Explanation of Figures.

FIG. 1.—Transverse Section of Optic Nerve stained in Hæmatoxylin, immediately distal to the entrance of the central vessels (*a. c.*). *x*, wedge-shaped area of proliferated corpuscles; *x*₁, neuritis extending across to nasal side of nerve; *y*, portion of nerve-sheath infiltrated with leucocytes; *n. s.*, nerve sheath.

FIG. 2.—Transverse Section of Optic Nerve stained in Weigert's Hæmatoxylin, proximal to entrance of central vessels. The dark shading shows the relative amount of healthy nerve-fibres existing. *t*, temporal side; *n*, nasal side. The greatest amount of degeneration is on the temporal side of the nerve.

A CONTRIBUTION TO THE PHARMACOLOGY OF
CURARE AND ITS ALKALOIDS. By JOSEPH
TILLIE, M.D., *Assistant to the Professor of Materia
Medica in the University of Edinburgh.* (PART II.)

(Continued from page 406.)

*The Physiological Relation between Curarine and
Methyl-Strychnium.*

IN this paper I propose to show that when strychnine is converted into an ammonium base, the new substance produced not only acts as a paralysing but also as a tetanising poison.

Theoretically it seems a little strange that a natural alkaloid (probably an ammonium base) like curarine—the type of those poisons which paralyse the endings of motor nerves—should at the same time be a convulsant poison of considerable activity, if it be correct that strychnine—the type of convulsant poisons—has its normal motor paralysing action intensified, but its characteristic spinal action destroyed, when it is artificially converted into an ammonium base by the addition of iodide of methyl.

Even the simplest compound ammonium salts have some special actions of their own, apart from that paralysing action on motor nerve ends which Crum Brown and Fraser¹ and other later writers have shown to be so general.

For example, 0·01–0·02 gramme of a tetra-methyl-ammonium salt causes in a frog, a few minutes after subcutaneous injection, stoppage of the heart in diastole,—an effect which is apparently due to stimulation of the inhibitory apparatus, for it is weakened or prevented by the administration of atropine. The same dose of a tetra-ethyl-ammonium salt had not this cardiac action, but caused before the motor paralysis very marked fibrillary muscular twitching,—an effect which is apparently due to a preliminary stimulation of the motor nerve ends, for it occurred, although the nerve trunk was divided, but

¹ *Trans. Roy. Soc. Edin.*, 1868, vol. xxv.

not when curarine was administered. It is easy also to determine that various characteristic actions of certain natural alkaloids remain in their ammonium derivatives. For example, methyl-atropium¹ dilates the pupil as atropine does. Other actions of the original alkaloids, however, are apt to be concealed and overlooked, not so much perhaps from any true changes in the kind as in the degree of pharmacological action, and from the changes in symptoms and other modifications introduced by the increase in the paralyzing action.

It seems desirable, therefore, to examine carefully into the nature and completeness of the experimental evidence upon which is founded the prevailing view of the action of methyl-strychnium salts.

*Stahlschmidt*² prepared and experimented with the methyl-strychnium salts in 1859. He found that doses which were very large, when compared with active doses of strychnine, were, in the rabbit, without poisonous activity; and he concluded, therefore, that the new body was inert.

*Schroff*³ experimented in 1866 with the nitrate of methyl-strychnium. He found that it caused symptoms of paralysis of a curare-like kind. Reflex tetanus sometimes occurred at recovery, and Schroff sought to explain this by the supposition that strychnine was liberated in the body by the decomposition of the methyl-strychnium salt.

Crum Brown and *Fraser*⁴ made, in 1867, an extended series of observations on the ammonium bases obtained from some of the more important alkaloids.

These observers found that the methyl and ethyl-strychnium salts were much less poisonous than strychnine, and that a true curare-like paralysis of the ends of motor nerves was the cause of death, and not tetanus. Doses less than the minimum complete paralyzing dose were not fatal, and caused a greater or less degree of paralysis, but no symptoms of spasm.

On pages 195, 196, and 197 the authors give a summary of their experiments with the iodide, nitrate and sulphate of methyl-strychnium, and with the hydrochlorate of ethyl-strychnium.

The recorded experiments with these salts are 34 in number, of which 25 were on rabbits, 2 on cats, 1 on a dog, and 6 on frogs.

Since a convulsant action on the cord, which is later in point of time than a paralyzing action on motor nerve endings, cannot be seen in ordinary experiments on warm-blooded animals, attention

¹ *Crum Brown and Fraser, loc. cit.*, p. 707.

² *Pogendorff's Annal.*, 1859, Bd. 5108, s. 513-523, &c.

³ *Wochenbl. der Zeitsch. der K. K. Gesel. in Wien*, 1866, vi. s. 157.

⁴ *Loc. cit.*

need only be directed to the recorded experiments on protected frogs.

The details¹ of these experiments show that the attention of the authors was really directed to the paralysing action on motor nerve endings. While it is clearly established that the immediate symptoms differ from those produced by strychnine salts, the duration of the observations was too brief, and the doses of the poison were too small to allow the absence of tetanic symptoms to be more than a proof that excitation of the cord is not a very early action of small doses of methyl-strychnium salts.

Jolyet and Cahours experimented in 1868 with methyl-strychnium salts, and found that small doses caused paralysis in unprotected frogs in 15 to 20 minutes. Larger doses produced symptoms of tetanus in protected frogs, some time after the motor nerves had lost their excitability. These tetanic symptoms were weaker and of much shorter duration than those produced by strychnine.

Crum Brown and Fraser,² in criticising these experiments, suggest that the convulsive movements could readily be explained by the presence of strychnine as an impurity in the methyl-strychnium salt. They remark, further, that some of the specimens first employed in their own experiments were found to give similar symptoms. This was found to be due to the presence of strychnine as an impurity, for, on treating the salt a second time with iodide of methyl, the convulsant symptoms were removed.

*Buchheim and Loos*³ also experimented on frogs with the methyl and ethyl derivatives of some of the alkaloids, among others with methyl and ethyl-strychnium. It is evident from the character of their experiments that they did not specially look for any tetanising action. Their chief work consisted in determining the intensity of the paralysing action of the different derivatives. The great majority of their experiments were on unprotected frogs. In protected frogs no observations are recorded later than the onset of complete paralysis in the unprotected parts. In one or two cases, after the administration to protected frogs of incomplete paralysing doses of ethyl-strychnium sulphate, some spasmodic symptoms were observed, and, as in the case of other authors, those symptoms were attributed to the presence of strychnine as an impurity.

*Valentin*⁴ experimented on muscle in 1873 with an iodide of methyl-strychnium obtained from Flückiger, and with a sulphate of methyl-strychnium obtained from Fraser. He found, before recording the muscle curves, that the iodide (p. 229), in small doses in unprotected frogs, caused feeble strychnine-like spasms. Larger doses caused paralysis. The sulphate (p. 234), when it acted slowly or feebly (1.5 mgm.), produced symptoms resembling those caused by the iodide; but in a dose of 4 mgm. it caused complete paralysis in three or four minutes, without any appearance of spasm.

¹ *Loc. cit.*, p. 162.

² *Proc. Roy. Soc. Edin.*, 1869, p. 560.

³ "Die Pharm. Gruppe des Curarins," *Eckhard's Beiträge*, Bd. v. s. 205, 1870.

⁴ *Archiv. f. Physiologie*, Bd. vii. s. 229, 1873.

All that can be logically deduced from the experimental evidence on the subject on the negative side is, that small doses of pure methyl-strychnium salts do not cause tetanus in protected frogs in the initial stage of the poisoning,—the longest recorded observations being twenty minutes after subcutaneous injection.

We have no knowledge that pure methyl-strychnium salts do not produce tetanus at a later period of the poisoning, and there is good ground, therefore, for making more extended observations with perfectly pure preparations.

The first specimen—a chloride of methyl-strychnium—was received from Professor Böhm in 1887. The chloride of methyl strychnium had been prepared from the iodide (obtained by Stahlschmidt's process) by mixing it with recently precipitated chloride of silver, the filtrate from the iodide of silver being evaporated until crystallisation had begun and all these crystals rejected. As the base strychnine is only slightly soluble in water, any unacted (?) upon by the iodide of methyl might be expected to be got rid of. The crystals obtained on further concentration had been recrystallised from *absolute* alcohol, in which strychnine is practically insoluble. The crystals showed under the microscope as fine glistening needles, readily soluble in water.

In order to compare the results obtained with this specimen in Leipzig in 1887, I obtained in Edinburgh, in 1889, from Messrs Duncan, Flockhart. & Co., a specimen which they specially prepared for me with a view to perfect purity.

The absence of strychnine or any salt of strychnine was proved and secured as follows:—

1. When a saturated watery solution was rendered alkaline by sodium carbonate, and allowed to stand for several hours, not the least trace of a precipitate formed.
2. When shaken well with chloroform the alkaline solution yielded only a trace of substance which was not strychnine.
3. As the iodide is not freely soluble in water, I prepared a sulphate by mixing a hot solution of sulphate of silver with a solution of the iodide, precipitating the excess of the silver salt with sodium chloride. After evaporation, the methyl-strychnium sulphate was recrystallised from absolute alcohol, and obtained in the form of tufts of fine

needle-shaped crystals. A 5 per cent. solution was then made by dissolving 0.5 gramme in 10 c.c. distilled water. On rendering this alkaline with sodium carbonate no precipitate formed. Assuming that the alkaline solution might contain a trace of free strychnine without showing a precipitate, it was repeatedly shaken up with successive quantities of chloroform, in which strychnine is very much more soluble (about 1 in 6) than in water (about 1 in 6000). The watery solution was finally filtered, neutralised with dilute sulphuric acid, evaporated to dryness, and extracted with a small quantity of absolute alcohol, sufficient only to dissolve out 0.259 gramme of the sulphate, which was obtained again in the form of tufts of fine needle-shaped crystals.

The results obtained in Leipzig with the pure chloride of methyl-strychnium were confirmed on pithed frogs with this pure sulphate.

EXPERIMENT IV., October 1887.—*Intact Frog, weighing 37.0 gm.*
Posterior Extremities protected as in Experiments with Curarine.
0.003 gm. Methyl-strychnium Hydrochlorate subcutaneously.

- 10 min. Motor paralysis in unprotected parts complete.
- 14 " Pinching anterior extremities caused vigorous movement of posterior extremities, the frog, which had been placed on its back, turning over.
- 20 " Reflexes good.
- 30 " Reflexes very difficult to obtain.
- 50 " During the last 20 minutes not the least spontaneous movement has occurred, and no stimulation has been applied.
- 55 " 1 pinch followed by a single extension of the legs.
- 56 " 3 pinches followed by a single extension of the legs.
- 57 " 6 pinches followed by a single extension of the legs.
- 58 " 34 pinches followed by a single extension of the legs, the reflexes being depressed or easily exhausted.
- 75 " Reflexes much more acute. Every stimulation, wherever applied, causes a sudden jerk.
- 80 " Drops of water allowed to fall from a height of a few inches on to any part of the body causes, time after time, an instantaneous jerk in the protected extremities.
- 1 h. 40 m. Reflexes exceedingly acute.
- 1 h. 42 m. Reflex tetanus lasting 4 seconds.
- 1 h. 50 m. Distinct reflex tetanus, which gradually, on further stimulation, became briefer and weaker.

This experiment shows that although motor paralysis was complete in the unprotected parts in *ten minutes*, there was not the least sign of exaggeration of reflexes until more than an hour after the poisoning—indeed, on the contrary, the reflexes were depressed—and distinct reflex tetanus was not obtained for nearly *two hours*, and then weakness quickly set in.

On administering 0·01 gramme to a frog weighing 43 grammes, motor paralysis of the unprotected parts followed in about *three minutes*. Up to thirty to thirty-five minutes after the poisoning the reflexes were depressed, but the movement of the lower extremities was vigorous when it did occur. The reflexes then rapidly became more and more acute, and *fifty-five minutes* after poisoning marked tetanus followed stimulation. Half an hour later there was almost complete exhaustion.

The second set of experiments with the pure sulphate of methyl-strychnium led to the same results. In pithed frogs the administration of 0·005 gramme seldom caused spasmodic symptoms before an hour or an hour and a half. Soon after the tetanus signs of spinal paralysis set in,—a condition due in part apparently, as with curarine, to a distinct circulatory depression, and in addition, perhaps, to a direct disturbing influence of the poison on the cord.

Some of the fallacies, therefore, which occur in the examination of curare by subcutaneous injection seem common, more or less, to those bodies which paralyse the endings of motor nerves, probably because they at the same time depress the vasomotor nerves.

This is well shown when three different methods of experimenting are adopted, the last method giving invariable results, and checking any obscurity caused by defective absorption and circulation of the dose in the first method.

In one experiment, after the cerebrum had been destroyed, the heart was exposed in a protected winter frog and found to be beating at the rate of 22 per minute, the energy being good, and the cavities well filled during diastole. On injecting subcutaneously 0·005 gramme methyl-strychnium sulphate, dissolved in ·2 c.c. water, the heart after a few minutes began to show a slight diminution in volume, and this was quite noticeable by the end of 15 minutes. After 40 minutes the heart seemed quite empty, and resembled that of a frog where complete vasomotor paralysis had been caused by the destruction of the

spinal cord. After a little more than an hour the reflexes in the protected part became *spasmodic*.

In a *second* experiment, after the brain was destroyed, the spinal cord was exposed and the heart ligatured.

During ten minutes the frog remained quite motionless, with the lower extremities flexed. The reflexes were then tested and found to be active and quite simple. One-tenth of a c.c. (.1) of water, containing about 0.002 gramme of the sulphate in solution, was then dropped into the spinal canal. The frog remained motionless for about *seven minutes*, and then *very sharp spontaneous tetanus* set in. During the next thirty minutes the faintest touch applied to any part renewed the spasms.

In the *third* experiment, a solution (about .3 c.c.) containing 2 or 3 milligrammes of the sulphate was injected directly into the aorta after the preparation described in the experiments with curarine. *Violent tetanus immediately followed*, and continued for about three quarters of an hour.

The spasmodic symptoms appeared in the first case after an hour, in the second case after seven minutes, and in the third case almost instantaneously.

The somewhat lengthy and very deceptive delay in the appearance of tetanus, after the subcutaneous injection of pure methyl-strychnium salts, is not due, therefore, to any intrinsically tardy direct action on the nerve centres, but apparently rather to impairment of the circulation,—the later slow absorption and diffusion of the poison not readily allowing the amount sufficient to produce the symptom to reach the cord.

These results show clearly that there is a distinct convulsant action, which is not due to the presence of strychnine; and which, owing to the brief duration of their experiments, could not have been demonstrated by the writers who came to a negative conclusion.

In methyl-strychnium salts the tetanising action of strychnine on the cord is delayed and diminished, and the paralyzing action of strychnine on motor nerves is hastened and increased.

Curarine, a natural alkaloid, which is probably an ammonium base, and which is derived from the same botanical family as strychnine, has also, we have seen, the actions of the artificial ammonium base, methyl-strychnium; and methyl-strychnium, in the relative order and strength of the paralyzing and tetanising actions, resembles curarine rather than strychnine.

The addition of iodide of methyl does not, therefore, produce any true change in *the kind* of the fundamental actions of strychnine, but a modification in the relative intensity and order of occurrence of these actions, and thereby changes in the poisonous activity and symptoms.

(To be continued.)

THE NATURE OF THE GIANT-CELLS OF TUBERCLE
AND THE ELEMENTS ASSOCIATED THEREWITH,
AS SEEN IN COMPARATIVE PATHOLOGY. By
WALTER K. SIBLEY, M.B., B.C., B.A. Cantab. (PLATE
XIX.)

LITERATURE abounds with the most opposite views held from time to time by various writers on tuberculosis, with regard to the nature, significance, and origin of the tubercular elements. It would be very difficult even to suggest anything on this subject, which, if the whole literature was carefully perused, would not be found in some form or other. It is therefore rather to help to confirm certain theories propounded by some authors concerning especially the origin of the tubercular elements, that it seems worth while to record the following observations. The conclusions are somewhat similar to those of Hering, Koester, Rindfleisch, and Klebs, and were arrived at from a consideration of the subject from a different method before the writings of those authors were studied; but they possibly more accurately describe the disease as a whole.

Writers on the subject have until recent years derived their conclusions almost, if not entirely, from the study of the disease in man. Already a few have gone a great stage further, and have made observations of the disease in some of the lower mammals, especially in guinea-pigs and rabbits. Still more recently comparative pathologists have studied it in birds; but these, so far, have not made any very great advance upon our previous knowledge concerning the nature of the processes by not comparing those found in different classes of animals one with the other.

From the study of the evolution of tuberculosis from the lower vertebrates up through the avian class into the higher mammals, the conclusion arrived at is, that the disease *primarily occurs in the lymphatic system*, and that in many of the lower forms it is apparently entirely confined to this. In Snakes

chains of tubercular deposits were found in close relation to the upper regions of the aorta which were undoubtedly in the lymphatic vessels. Also in the viscera the deposits were encapsuled as if by a vessel wall. Again, the structure of these deposits in the viscera was exactly the same as that of the thrombosed lymphatic vessel by the aorta. So that in these examples there occurred a thrombosis and nodular deposit in the main and in the smaller lymphatic vessels in various regions of the body.

So also in Birds, often the deposits were distinctly observed in the lymphatics; for instance, in a swan examined there was complete tubercular thrombosis of a large number of the abdominal lymphatics, not only those in relation to the great vessels, the vena cava and mesenteric, but also in the lymphatic channels lying in relation to the abdominal air-sacs; the diseased vessels forming irregularly beaded, cord-like structures on the surface of the same.

In examining sections of the intestine of an Owl (figs. 1 and 4) under the microscope, where the whole wall of the gut was much increased in thickness, as occurs about the seat of tubercular lesions, it was found that in the earlier stages, that is, previous to caseous degeneration, the increase of tissue consisted almost entirely of groups and columns of *epithelioid cells* full of tubercle bacilli, in the substance of the mucous membrane, and often extending through the muscular into the serous coats. Thus small tumour-like formations were seen especially marked in the submucous tissues, the cells of which were arranged, some in columns and some in more or less rounded groups; and from these groups and columns similar cells were seen piercing the outer walls of the intestine, often at right angles to the long axis of the gut. In examining more minutely these epithelioid cells, they were seen to be undoubtedly lying in vessels, and in fact were the proliferated endothelium of the same.

Groups of the same nature occurred in the viscera, such as the liver and spleen, often very abundantly; in section usually more or less round, occasionally oval or elongated, sometimes angular, and often clearly in vessels. The same appearances were found in a great number of birds, and were usually more

distinctly marked in carnivorous than graminivorous forms. From the above descriptions it is observed that in many places vessels with proliferating endothelium were seen, which when cut in their long axes appeared as columns of epithelioid cells, and when cut transversely appeared as roundish groups of the same cells, in some places, before degeneration had taken place, forming small localised tumours; those in the intestinal mucous membrane, when examined with ordinary staining fluid reagents had the appearance of a carcinomatous growth (fig. 4), each collection or group of cells being formed of well-stained nucleated granular epithelioid cells enclosed by a few bands of fibrous tissue. The whole deposit consisted of a mass of these groups of cells, some round, some oval, and some in columns, according to the plane of the section. When stained by any of the recognised methods for demonstrating the presence of tubercle bacilli, each of these epithelioid cells was seen to be crowded with bacilli, these clearly lying in the cells themselves, and often in close relation with the nucleus.

In examining such an organ as the liver and finding changes in the vessels, we must, in the first place, determine what vessels are normal, and then a better idea can be formed as to the exact kind of vessel which is the seat of the lesions. That is to say, in the case of the liver all the systems of vessels must be separately examined—such as the portal veins, hepatic arteries, hepatic veins, bile-ducts, and the lymphatics. The several systems, with the exception of the lymphatics, can in most animals be easily determined. Following this plan of procedure, in most cases of tuberculosis in birds the main vessels of the organ were found to be normal, that is to say, the walls and lining endothelium of the hepatic veins in the centre of the lobules and the large branches of the portal veins associated with the branches of the hepatic artery and bile-ducts at the periphery of the lobules appeared in most cases to be healthy. So, by this process of exclusion, the deposits in the liver must be in the lymphatics.

Investigation by this process cannot be so definitely carried out in the other organs or parts of the animal's body, and hence the great importance of a very thorough examination of the liver in all cases.

In tuberculosis in birds the spleen usually presents more marked changes than any other organ or part. This is what we should expect from its lymphatic nature and constitution. In fact, it appears probable that the distribution of the organs that are chiefly or primarily affected in the various classes of animals will be found to depend very greatly upon the arrangement of the lymphatics in similar organs in the different classes of animals. Thus the lungs are chiefly affected in the adult human being, and the spleen and liver in birds, &c.

Being, from the above examples, satisfied that the disease is primarily in the lymphatics, I found, in examining sections of the organs of a large number of birds, that in some examples, many of the deposits were undergoing some degenerative change. This was especially marked in the case of a Dove, sections of whose liver and spleen showed much the same appearance of groups of epithelioid cells. Thus groups of typical epithelioid cells occurring around the internal wall of vessels and surrounding the central thrombosis were seen in places. Each of these cells was distinct in outline (fig. 2a). Other groups occurred in which the outline of the individual cells was not so distinct; some again in which, in certain parts of the group, the outlines of the cells were distinct, and in other parts were much obscured (fig. 2b). In some groups, or parts of such, the outlines of the cells had disappeared, the nuclei alone showing their original nature and distribution, these always remaining clear and distinct. Stages more advanced occurred where all the outlines of the individual cells had disappeared, the cells being only represented by their persistent nuclei (fig. 2c). As these stages were traced up, so the whole vessel became more and more irregular in outline; and here the typical giant-cell of tubercle was found, characterised by the fact that the nuclei were generally arranged either around the circumference of the cell, or, at any rate, more at one or other pole, very rarely in the centre (fig. 2c). Thus the opinion held is, that the giant-cells of tubercle are *thrombosed lymphatic vessels with proliferated endothelium in section*. This view explains the reason of the generally acknowledged disposition of the nuclei, this depending chiefly upon the following factors:—(1) The relative amount of endothelial proliferation to the thrombosis of the original fluid contents of the lymphatic;

and (2) the plane of the section of the vessel. Thus, if a more or less regular endothelial proliferation around the inner wall of the vessel has occurred, together with a certain amount of thrombosis of the fluid contents of the lumen of the vessel, in section a distinct more or less round ring of nuclei is seen towards the peripheral regions of the so-called giant-cell. If, on the other hand, the endothelial proliferation has occurred irregularly, more abundantly in some regions than in others, more excessively for instance, on one side of the vessel, so in transverse section would the nuclei appear more or less at one pole of the giant-cell, namely, at that at which the abundant endothelial proliferation had occurred. And so a great variety of nuclear arrangement is found depending upon this endothelial proliferation and the plane of section of the vessel.

In most cases tubercle bacilli abounded in close relation to the nuclei in the epithelioid cells, so that, when a section was stained for these organisms, the groups of epithelioid cells were seen only as a mass of bacilli so crowded together that the individuals could not be made out. Also, in the early formed giant-cells with this ring of nuclei, these with the aniline dyes showed a complete ring of bacilli around the internal wall of the vessels, leaving the central regions of such vessels quite free from bacilli. Although the above description is confined entirely to lymphatic tuberculosis, I would not maintain that the deposit may not, and, in fact, often does occur in other kinds of vessels, or that in some cases the elements of tubercle may not be derived from other sources than the endothelium of vessels alone, but such I should consider to be the exception and not the rule.

The stages in the formation of tubercle appear to be briefly as follows:—After a coagulative thrombosis of the lymphatic vessel has occurred, and the endothelium has by its proliferation given rise to a group of epithelioid cells, which soon, by the disappearance of their cell walls and preservation of their nuclei, becomes the so-called giant-cell.

One lymphatic being blocked, probably numerous others become formed in the immediate neighbourhood, so a process of proliferation of the lymphatic radicles all about occurs, and the corresponding spreading of the tubercular deposits to parts

around, that is, the characteristic local dissemination of the process, the so-called infective distribution.

Then the other cells of the original vessel-wall, with their nuclei, multiply and form a zone of epithelioid cells, which occasionally, by a process of similar fusion through degeneration of their walls, form secondary smaller giant-cells around the central one. At the same time the vessel wall becomes infiltrated with small round cells. And so the generally described three-zoned tubercle is formed, namely, a central *giant-cell* surrounded by *epithelioid cells*, and these again by *granulation tissue*; and the whole is surrounded by the more or less broken up vessel-wall of fibrous tissue, which sometimes forms a distinct capsule. At other times it is surrounded apparently by the small-celled infiltrated vessel wall, which appears only as strands of fibrous tissue in the peripheral regions of the deposit.

The first part to show caseous degeneration is the oldest formed, or that part which has already lost its vitality in its production, namely, the central giant-cell.

It will be seen that, according to the above description, a giant-cell of tubercle is essentially a dead or dying substance and not a living organism, and thus differs completely from giant-cells found in healthy structures, such as the myeloplaxes of the marrow of bone, &c., and the true actively growing giant-cells found often in inflammatory processes and in many varieties of new growths, especially in the large-celled sarcomas and similar developments. In all of these latter cases the cell is assimilating nutrient material from the tissue around and living, that is, growing and reproducing itself—in fact, an active mass of protoplasm, produced by rapidly dividing up of nuclei of the cell with active growth without a corresponding division of the cell protoplasm.

In tubercle, on the other hand, the giant-cell, from its very earliest differentiation as such, is essentially dead or dying—a false or pseudo giant-cell,—and is produced by processes which are essentially retrogressive, namely, a breaking down of the continuous walls of cells, and this without a contemporary division of the life principle of the cells, that is, of their nuclei.

Strictly speaking, no limitation can be stated of the giant-

cell so produced neither as to its beginning nor as to its ending.

When, then, can we speak of these as giant-cells? At first a group of more or less similar cells of an epithelioid nature, each perfect in outline and with its own nucleus; then one or more of the contiguous cell-walls disappear, the nuclei remain and constitute a so-called giant-cell. And then, later, when all the intervening cell-walls have disappeared, the cell, or rather at this period the mass of partially degenerated protoplasm, will go on slowly extending, increasing in size by a process of extension irregularly into the areas immediately around. This increase of the necrotic centres is probably due to a molecular death of those parts of the deposit which are lying in immediate contact with the already dead central caseation, either from causes inherent in the morbid products themselves, or, as appears likely from our general knowledge of diseases produced by, or intimately associated with, micro-organisms as the result of some chemical poison produced in process of their growth and reproduction. The structures, which previously might have been spoken of as giant-cells, become caseous masses. The term giant-cells for these is unfortunate, seeing how essentially different they are from true living giant-cells, and much confusion has necessarily arisen from this. Thus a writer on avian tuberculosis has described large caseous masses, which had lost all trace of their original cellular origin, and now are merely structureless granular masses of dead tissue lying in the centres of old tubercles, and these the writer speaks of as large giant-cells.

If the term giant-cell must be retained for convenience of descriptive purposes, we surely should only apply it as long as there is clear evidence of the cellular origin, that is to say, as long as nuclei or other signs of cell-life are demonstrable.

From the above description it follows that none of the so-called elements of tubercle, the giant-cells, epithelioid cells, or small round cells, are of themselves essential to the formation of the tubercular granuloma, and the presence of any one depends upon the stage of the deposit. If any one element is all important it is the epithelioid cell.

Part of some giant-cells may be formed by the original convol.

tents of the vessels. It is also probable that some of the epithelioid cells around may be formed by the deeper seated endothelial cells which have not taken part in the formation of the original giant-cell, as well as by other cells of the vessel wall.

With regard to the part played by the Bacilli, one point is quite certain, namely, that they are not the immediate cause of the necrosis of the tubercular deposits, as is maintained by most authors. For instance, Zeigler, in his *Pathological Anatomy* (English translation by Donald Macalister), states "the necrosis of the tubercles is well considered a specific action of the bacilli." Now, on the one hand, we find that in many birds enormous numbers of bacilli are found without any very marked degenerative change in the containing tissues; and, again, frequently the bacilli are not found in the regions where the necrosis is actually taking place, but in those areas where all active degeneration has ceased. Thus, in the deposits occurring in the viscera of fowls (fig. 3), consisting of a large area of central necrosis surrounded more or less by granulation tissue, the curious arrangement of the bacilli to the necrosis has been noted by Ribbert¹ in his paper "On Tuberculosis in Hens," who writes, "remarkable is it that the molecular atrophy in the middle of the nodules does not keep pace with the extension of the bacilli, but that between the bacilli containing tissues and the atrophied centre an area free from bacilli exists."

I have made the same observation from several classes of birds,² and also from snakes.³

In the deposits occurring in the solid organs, the bacilli in the central necroses abound, not at the extreme periphery where the process is active (fig. 3, *c*), but in the zone internal to this (fig. 3, *b*). So again, in cases of large tubercular pouch-like projections in the walls of the digestive tract of fowls, the bacilli do not abound in the deeper regions, that is to say, at the line of junction of living and dead tissues, where the process of transformation of living into dead tissue is taking place, but in the older (and now through the molecular atrophy of the centre of such deposits, more superficial) regions where the process of crumbling away is occurring.

¹ *Deut. Med. Wochens.*, 1888.

² *Trans. Path. Soc. Lond.*, 1888.

³ *Virchow's Archiv*, Berlin, 1889; and *Jour. Anat. and Phys.*, 1889.

That the bacilli can be the cause of the disease there can be no doubt, and with regard to their rôle one of two modes of action is possible—(1) That the introduction of bacilli, as such, by their active multiplication within the lymphatic system, gives rise mechanically to the onset of the disease, that is, to the proliferation of the lymphatics and their endothelium; (2) or that some chemical poison is produced by their growth in the animal's body, and this substance starts the disease.

For either of these to occur a probably specific condition of tissues essential to the development of tuberculosis must be present in the body in which the bacilli are enabled to germinate and multiply. That the extent and capability of their multiplication depends upon some condition of tissues, that the presence and progress of the disease is regulated by some inherited or acquired "nutrient medium" is generally acknowledged. Thus with our present knowledge we say that there must be two factors for the development of tuberculosis, the soil and the specific micro-organism, and possibly of the two the former is the more important.

If all the essential conditions favourable for the rapid development of the bacilli be present in the body, from their active multiplication in the lymphatic system they soon find their way into the blood system, and produce what is known as "acute tuberculosis" in man, in which occurs not only tubercular deposits in the lymphatic, but also in the venous system, and here the bacilli are to be found in the blood itself. The same process may occur in the lower animals, but rarely appears to be acute, and only after old-standing "lymphatic tuberculosis" does tubercular thrombosis of the venous radicles in various parts of the body take place.

EXPLANATION OF PLATE XIX.

Fig. 1. Section through the small intestine of an Owl, showing the groups of bacilli (*d*) in the lymphatic vessels piercing the muscular coats (*b*), and in the mucous membrane (*a*) much infiltrated with small round cells, and groups of epithelioid cells containing bacilli (*e*). Hardened in alcohol, stained in Ziehl's solution of fuchsin,

decolorised by dilute acid and alcohol. Mounted in Canada balsam. Magnified 52.

Fig. 2. Giant-cells from the spleen of a Dove, in various stages of formation from the proliferated endothelium in the lymphatic vessel (a), the same in which the outlines of some of the cells are lost, the nuclei alone remaining (b) more advanced where all the outlines of the cells are gone; the multinucleated giant-cell (c). Hardened in alcohol, stained in hæmatoxylin, and mounted in Canada balsam. Magnified 230.

Fig. 3. Tubercular deposit from the liver of a Fowl, with caseous centre. (a) degenerated giant and epithelioid cells around (c) groups of bacilli (b), towards the peripheral region of caseation, granulation tissue (d) with some fibrous tissue remnants of the original vessel-wall (e), and the whole enclosed by liver cells (f). Hardened in alcohol, stained by Gibbes' method, and mounted in Canada balsam. Magnified 52.

Fig. 4. A section through an early tubercular deposit in the intestinal mucous membrane of an Owl; (a) normal tubular gland; (b) groups of epithelioid cells; (c) small round-celled infiltration; (f) muscularis mucosæ. Hardened in alcohol, stained in alum carmine, and mounted in glycerine. Magnified 435.

THE STERNUM AS AN INDEX OF SEX, HEIGHT,
AND AGE.¹ By THOMAS DWIGHT, M.D., LL.D., *Parkman Professor of Anatomy at Harvard University, U.S.A.*

IN a short paper published in the *Journal of Anatomy and Physiology*, vol. xv., 1881, I gave the measurements of the sterna of 30 men and 26 women, and discussed the correctness of Hyrtl's statement, that it is hardly possible to err in determining the sex of this bone, and that "the manubrium of the female sternum exceeds half the length of the body, while the body in the male sternum is, at least, twice as long as the manubrium." This small series gave for the male a mean length of 5.18 cm. for the manubrium and 10.58 cm. for the body (total, 15.77 cm.), and for the female 4.67 cm. for the manubrium and 8.95 cm. for the body (total, 13.62). Thus the law was shown to hold good for the mean sternum in both sexes, but yet it failed to apply to 12 of the 30 men and to 14 of the 26 women.

In the same year Strauch presented an inaugural dissertation at Dorpat, which I know only through an abstract in *Hofmann and Schwalbe's Jahresberichte*. He measured 200 bones, apparently including the ensiform cartilage. The mean length of the manubrium is not given in the abstract, but we are told that in the male it is .007 cm. shorter than in the female. The difference of length between the sexes is practically wholly in the body, which is on the average about 2 cm. longer in man (11 cm. and 9 cm.). Strauch found that the different parts of the male sternum are in general absolutely thicker and broader but relatively thinner and narrower than in the female. In male and female sterna of equal length the former has a narrower manubrium, and the latter greater breadth at the lower part of the body. He found that in man the length of the

¹ From a paper entitled "Medico-Legal Studies on the Human Skeleton," read December 27, 1889, at the meeting of the Association of American Anatomists at Philadelphia.

manubrium is to that of the body as 1 to 2.1, and in woman as 1 to 1.7, thus again confirming Hyrtl's law for the mean.

TABLE I.—*Length.*

Cm.	Manubrium.		Body.		Total.	
	Men.	Women.	Men.	Women.	Men.	Women.
2.5	1	...	...	...	...	...
3.	1	...	...	...	...	...
3.5	3	2	...	...	...	...
4.	9	16	...	...	...	...
4.5	15	21	...	...	...	...
5.	49	29	2	...	...	...
5.5	35	14	...	...	...	...
6.	20	8	...	...	...	...
6.5	4	1	...	2	...	...
7.	3	...	1	1	...	...
7.5	1	...	...	8	...	...
8.	...	...	...	10	...	...
8.5	1	...	2	14	...	...
9.	...	...	9	18	...	...
9.5	...	...	6	14	...	...
10.	...	...	33	7	1	...
10.5	...	...	17	5	...	...
11.	...	...	22	4	1	2
11.5	...	...	15	2	...	2
12.	...	...	13	...	...	5
12.5	...	...	10	1	3	4
13.	...	...	2	...	...	12
13.5	...	...	2	...	1	15
14.	...	...	3	...	8	13
14.5	...	...	1	...	8	9
15.	...	...	2	...	17	11
15.5	...	...	1	...	15	5
16.	...	...	...	...	22	3
16.5	...	...	1	...	17	2
17.	...	...	...	...	14	1
17.5	...	...	...	...	18	2
18.	...	...	...	...	4	...
18.5	...	...	...	...	1	...
19.	...	...	...	...	7	...
19.5	...	...	...	...	...	...
20.	...	...	...	...	2	...
20.5	...	...	...	...	1	...
21.	...	...	...	...	1	...
21.5	...	...	...	...	...	...
22.	...	...	...	...	...	...
22.5	...	...	...	...	1	...
Total,	142	86	142	86	142	86

The series I now present includes the one already published in this *Journal*. It represents measurements of 228 sterna,

of which 142 are male and 86 female. The means are as follow :—

	Manubrium.	Body.	Total.
Male, . . .	5.37 cm.	11.04 cm.	16.41 cm.
Female, . . .	4.94 „	9.19 „	14.13 „

Once more, we find that the proportions of the mean sternum follow Hyrtl's law, but a study of the individual cases shows that among the men 59.1 per cent. agree with it and 40.8 per cent. do not; while in women 60.4 per cent. agree and 39.5 per cent. do not. We conclude, therefore, that the law does not apply to two persons out of five, and thus can be of no value in the case of an individual.

It is best not to be content with taking an average, but to divide the sterna and their parts into groups of certain lengths, from which we may gain a more just idea both of the mean and of the range of variation. Table I. shows the number of bones, and of parts of bones, in each group, which includes all of the length indicated, and shorter than those of the next group.

This table also shows that the variation in the length of the manubrium is very slight. Of the male ones 119 are from 4.5 cm. to 6.5 cm., and all but 6 of the female from 4 cm. to 6 cm. The bodies vary more; still 110 male ones range only from 10 to 13 cm., and of the female 56 from 8 to 10 cm. The variation of the different parts, and consequently of the totals, is greater among men than among women, but the larger number in the male series must be kept in mind. The smallest sternum is a male one.

The Relation of the Length of the Sternum to the Height.—Strauch found that the length of the sternum (the ensiform being, no doubt, included) was $\frac{7}{8}$ of the height in man and $\frac{5}{8}$ in woman, but that there was no constant relation between the length of the bone and the height, as Körber¹ apparently had maintained. I know absolutely nothing further of Körber's observations. I have studied this question on 70 men and 39 women, all of whom were white. (There are a few observations on negroes in the preceding table.) The results are in some respects very remarkable. As a matter of course the average

¹ *St Petersburg Med. Zeitschrift*, iii. 2.

length of the parts of the sternum is not precisely the same as in the larger series. The first line of the following table shows the average height of 70 men, the length of the manubrium and of the body of the sternum, and the relation of the sum of these to the height taken as 100. I then divided the group into two equal ones of the 35 shortest and the 35 tallest respectively. In the shorter group the height ranges from 155.5 cm. to 169.5 inclusive, and in the taller from 169.6 cm. to 191.5 inclusive. I then picked out three groups—one of the 11 shortest men, ranging from 155.5 cm. to 163.7; one of the 13 tallest, from 176.1 cm. to 191.5; and a third group of 23 men from the middle of the series whose heights were very nearly equal, as they ranged only from 168 cm. to 170.8 cm. (all inclusive). Twelve of this group belonged to the shorter half and 11 to the taller.

TABLE II.—*Men.*

Group.	Height.	Manu- brium.	Body.	Total.	Percentage of Height.
70	169.9 cm.	5.5 cm.	10.9 cm.	16.4 cm.	9.65 per cent.
35 shortest	165.1 "	5.3 "	10.8 "	16.1 "	9.75 "
35 tallest	174.7 "	5.7 "	11.06 "	16.8 "	9.61 "
11 shortest	160.3 "	5.4 "	10.5 "	16. - "	9.98 "
23 middle	169.4 "	5.3 "	10.9 "	16.2 "	9.56 "
13 tallest	179.7 "	5.7 "	11.4 "	17.2 - "	9.57 "

We see that the total length of the sternum increases with the height in every group in due order, and that the same is true of the body, while the manubrium shows some variation. It is important to notice, however, that the proportion to the height varies in different groups much less than one would expect, knowing the range of individual variation. The variation in the percentage of the height formed by the sternum is, I think, surprisingly small. As might be expected, the percentage is larger in the shorter bodies than in the taller, though the table does not show a perfect regularity. The manubrium shows a general tendency to increase with the height.

I divided the 39 women into two groups of the 19 shortest and the 20 tallest, ranging respectively from 144 cm. to 156.7 cm., and from 157.2 to 171.2, all inclusive.

TABLE III.—*Women.*

Group.	Height.	Manu- brium.	Body.	Total.	Percentage of Height.
39	156.1 cm.	5.03 - cm.	9.3 cm.	14.4 - cm.	9.22 per cent.
19 shortest	151.5 "	5.02 "	8.9 "	13.9 "	9.17 "
20 tallest	160.4 "	5.03 "	9.8 "	14.85 "	9.26 "

The most striking thing in this table is the constancy of the length of the manubrium in all the groups. The next is that, while among women the sternum is shorter in proportion to the height than in men, it is relatively smaller in the shorter women than in the taller ones. I cannot but think, however, that this should be received with caution till the point is settled by a larger series. Curiously enough, the smallest percentage of the height is found in the sterna of the group of the 19 shortest women (9.17 per cent.) and the greatest in those of the group of the 11 shortest men (9.98 per cent.). Thus the extreme variation between all the groups is only .81 of 1 per cent.

We must now consider the variation among the individuals of the different groups. In that of the 11 shortest men the lowest percentage is 8.95 and the highest 11.06, but the next lowest is 9.24 and the next highest 10.67. The mean is 9.98. If we exclude the two extreme individuals, the variation is not great.

The mean of the 13 tallest men is 9.57, and the extreme limits 8.66 and 10.31.

The middle group of 23, with a mean percentage of 9.56 per cent., presents extreme variations of 8.41 per cent. and 10.60 per cent. Thirteen of the 23 are between 9 per cent. and 10 per cent.

Of the 35 shortest men, the extremes are 6.80 per cent. and 11.57 per cent. The former is, however, a very exceptional case, in which the combined length of the manubrium and body is only 11.4 cm. The next lowest is 8.41 per cent. There are ten below 9.25 per cent., of which two are 9.22 per cent. and 9.25 per cent. respectively. Nine are above 10.25 per

cent. Thus the mean being 9.75 per cent., 16 are within one-half of 1 per cent. of it.

Of the 35 tallest men, the smallest percentage is 8.58 per cent. and the largest 11.19 per cent. The latter is an uncommon case, the sternum being 19.22 cm. long. The next highest percentage is 10.91 per cent. The mean is 9.61 per cent.

The smallest percentage of the 19 shortest women is 8.01 per cent. and the greatest 10.35 per cent., and the next greatest 9.83 per cent. The mean is 9.17 per cent. Only three are more than half of 1 per cent. below it, and only six more than as much above it. Of the latter, two pass the limit by only .01 of 1 per cent.

The mean of the 20 tallest women is 9.26 per cent. The smallest is 7.27 per cent. and the next 8.18 per cent. The two highest are 11.38 per cent. and 10.49 per cent. Five are more than a half of 1 per cent. below the mean, of which two are near the line, and five are more than as much above it.

It would be necessary to exclude but a few cases to show a remarkably small individual variation from the means in the different groups. Certainly, as with Hyrtl's law, one would not be justified in attaching great weight to this guide to the height in a single case; but it seems to me probably as trustworthy a basis of estimation as the long bones, and perhaps even a better. I hope, at least, that some others may think it worth while to add to the number of observations.

The Ossification of the Sternum.—In my previous paper I expressed the opinion that the sternum is of little value as an index of age. I could remember, I stated, but very few instances of persons of 20 or over, in which the body was not one piece. This is, of course, in opposition to the entirely imaginary table still to be found in some standard works, according to which the third piece of the sternum (counting the manubrium as the first) joins the fourth at from 20 to 25, and the second at from 35 to 40. Further observation entirely confirms my views. I cannot even agree with some high authorities who state that the second piece often does not join the rest of the body till 25. I must add, however, that from a few observations, I incline to the opinion that the

several parts of the body unite later in the lower races. The dates of the union of the body with the ensiform, and of its less frequent union with the manubrium, are most uncertain. The following is a short statement of my observations on 46 male and 26 female bodies. The youngest was a girl of 17; in her case there was a broad strip of cartilage between the manubrium and the body. The first piece of the body was distinct from the rest, which was one piece of bone, showing a faint transverse line on its front surface at the junction of the second and third pieces of the body. There was no bone in the ensiform. This sternum is the only one in this series in which the body is not one piece. Unfortunately, there are no others younger than 25.

The Male Sterna.—These are 46 in number. The manubrium, body, and ensiform are all distinct in 18 cases of the following ages:—28, 31, 35, 37, 37, 38, 40, 41, 43, 43, 49, 54, 55, 62, 65, 68, 71, and 79.

The manubrium is distinct, and the body and ensiform are joined in 13 cases, aged—28, 31, 35, 37, 37, 39, 45 (black), 47, 55, 66, 70, 72, and 75. To this group may be added five cases, aged 51, 65, 68, 75, and 82 (?), in which the ensiform seems on the point of joining the body, or in which it is doubtful whether they are really united or not.

The manubrium, body, and ensiform are all co-ossified in seven cases. In the youngest, 25, the union of the body and ensiform had just begun. In two of 36 and 38 the union between the manubrium and body is only beginning. A man of 43 had extensive ankylosis of the spine. In one of 44 the union of the manubrium was just beginning, and that of the ensiform doubtful. One of 45 requires no comment. In one of 65 the union between the manubrium and body was slight.

The following three cases may be put together. In a man of 38 there was slight union between the manubrium and the body, the ensiform being distinct. In a negro of 42, the manubrium and body were partly co-ossified, while the ensiform was free and contained no bone. In the sternum of a white man of the same age, the manubrium and body formed but one piece of bone, while the ensiform, which contained little bone, was free. This sternum is so remarkable, owing to the apparent

prolongation of the manubrium to the third ribs, that it shall form the subject of a separate paper.

The Female Sterna.—The examination of 26 cases results as follows:—the manubrium, body, and ensiform are all distinct in 12 cases, aged as follows: 17 (described above), 26, 26, 31, 32, 33, 45, 50, 50, 60 (very little bone in ensiform), 65 and 80. To these may be added one of 39, of which it was recorded that the ensiform was probably distinct.

The manubrium was found distinct, and the body and ensiform joined in eight subjects of the following ages: 40, 44, 56, 60 (?), 64, 67, 82, and 91. The manubrium, body, and ensiform are all united in a specimen from a woman of 51.

The manubrium and body are united and the ensiform still distinct at 26 and 70. In a case aged 51 the manubrium and body were just beginning to join, the ensiform being still distinct.

The sternum of a negress of 38, which probably belongs in the first group, is sufficiently curious to deserve a special description. The manubrium and body are still distinct. The body, as seen from the front, ends at the level of the insertion of the fourth pair of costal cartilages. The fifth pair are attached to its lower end. The fifth, sixth, and seventh pairs of cartilages meet one another and their fellows of the opposite side, forming a cartilaginous continuation of the sternum. There is some calcification of the fifth pair at the sternum. Seen from behind, the body appears a little longer, a thin layer of ossification extending down between the fifth cartilages. The ensiform cartilage was almost wholly cut away. What little is left contains no bone, and appears to spring from the deep surface of the united costal cartilages. The specimen is a very pretty demonstration of Ruge's views of the development of the sternum from the costal cartilages.

These tables show that the body of the sternum is but one piece of bone at 25 years.¹ Probably a larger series would show

¹ Since reading this paper I have met with the sternum of a white man aged 46, in which union between the first and second pieces of the meso-sternum had evidently but just begun. The manubrium and ensiform were still free. I have also examined the bodies of a white woman of 20, of a negro of 20, and of a white man, an Armenian, of 21; in all the meso-sternum was in one piece.

some few exceptions, but I think it would show also that the bone is usually in this condition some years earlier. This belief is founded on scattered observations which could not be included in this series. These tables show also how utterly uncertain is the time of union of the manubrium and ensiform with the body of the sternum.

IRREGULAR UNION OF THE FIRST AND SECOND PIECES OF THE STERNUM IN MAN AND APES.

By THOMAS DWIGHT, M.D., LL.D., *Parkman Professor
of Anatomy at Harvard University, U.S.A.*

AMONG the breast-bones shown at the reading of the preceding paper at Philadelphia was a very remarkable one, which must be discussed in a separate article. It came from the body of a white man forty-two years old. His height was 164.6 cm., and the length of the bone (without the ensiform) is 16.5 cm. The peculiarity of this bone (fig. 1), consists in the

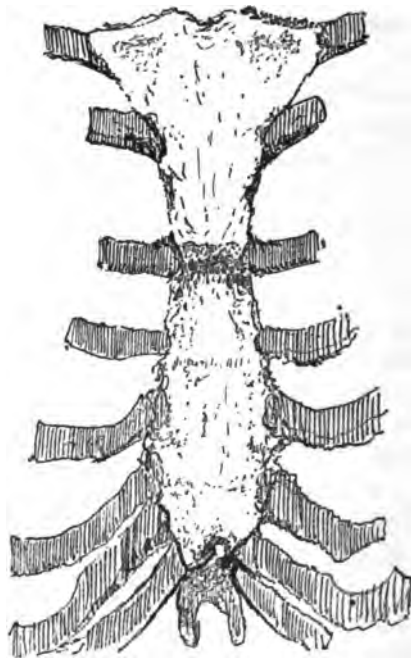


Fig. 1.

apparent continuation of the manubrium to the level of the third costal cartilages. It gradually narrows to that level, and there presents a strong transverse prominence which must have been felt with great distinctness through the skin, being,

I think, greater than the usual one at the lower border of the manubrium. There is a much slighter prominence at the same place on the back of the bone. The second ribs are very near the first, and the portion of the sternum above their level very short. It is only by very careful inspection that any inequality of the surface is seen on the front of the sternum between their ends, but an almost imperceptible thickening of the bone may be detected by the finger. There is no sign of a suture. The ensiform is separate, but the rest of the sternum is one piece of bone. Eight costal cartilages join it on the right. On the left the eighth just fails to reach it. The apparent manubrium forms nearly half the length of the bone.

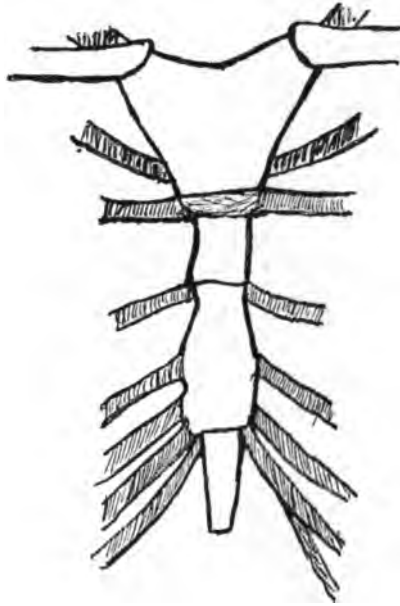


Fig. 2.

Dr Lamb, of the Army Medical Museum at Washington, expressed the opinion that all the bone above the third cartilages should be considered as the manubrium, and said that he thought this condition exists in some monkeys. On my return to Boston, I examined the skeletons in the Museum of the Society of Natural History, and looked through several works on comparative anatomy, without finding anything in support

of Dr Lamb's views. After a time, however, I received a letter from him, in which he stated that he had found this condition in the *Hylobates leuciscus*, and he informed me later that a diagram which he sent me of the sternum of this animal would do very well for that of the *Hylobates lar* also. I then visited the Museum of Comparative Zoology at Cambridge (Mass.), and found a skeleton of each of these animals. Fig. 2 represents rather diagrammatically the sternum of *Hylobates leuciscus*. The third ribs end against a strip of cartilage separating the manubrium from the next piece. The second ribs are but very little higher. Dr Lamb's diagram differs from mine chiefly in the point of insertion of the second ribs, which is about midway between those of the first and third ribs. The ossification of the meso-sternum is the same in both. The *Hylobates lar* at Cambridge is quite different. The only peculiarity is that the second costal cartilages touch the body of the sternum only by their lower edges resting almost wholly against the manubrium. There is no intervening strip of cartilage.

I am further indebted to Dr Lamb for calling my attention to a series of lectures by de Blainville, translated and edited by Dr Robert Knox, published in the *Lancet* of 1839-40. From these lectures I would quote the following passage about the Gibbons:—¹ "The sternum is large, short, approaching the human in form, and composed, in the adult skeleton at least, of three large portions—an anterior, which represents two very unequal sternobræ, and which in fact, supports two pairs of ribs, a central part of moderate dimensions, which corresponds to three or four sternobræ in the Callitriche, and with which, in fact, are articulated the other five pairs of sternal ribs; lastly, a third portion (xiphoid) of considerable length placed between the united cartilages of the asternal ribs." This is illustrated by the cut which is reproduced as fig. 3. It was taken from de Blainville's *Atlas*,² and represents the sternum of *Pithecus syndactylus*, now *Hylobates syndactylus*. It shows the meso-sternum bearing four pairs of ribs instead of five, according to the description just quoted. Dr Knox published in the same volume of the *Lancet* a memoir on the *Gibbon varié*, with a

¹ *Lancet*, 1839-40, vol. ii. p. 212.

² Vol. iv. plate viii.

critical examination of de Blainville's account of the gibbon. Dr Knox's observations are based on two gibbons which he had received undissected. One was an adult female, the other a young one. Of the former he wrote:—"The thoracic sternebrae are three in number; and in this respect, but more particularly in the flattened broad form of these portions, the sternum resembles the human sternum so closely as, we imagine, would deceive most anatomists. There are distinctly seven pairs of sterno-costal cartilages, and these are rather curiously placed, not being at equal distances from each other. The second and third pairs approach each other very closely, and would seem to

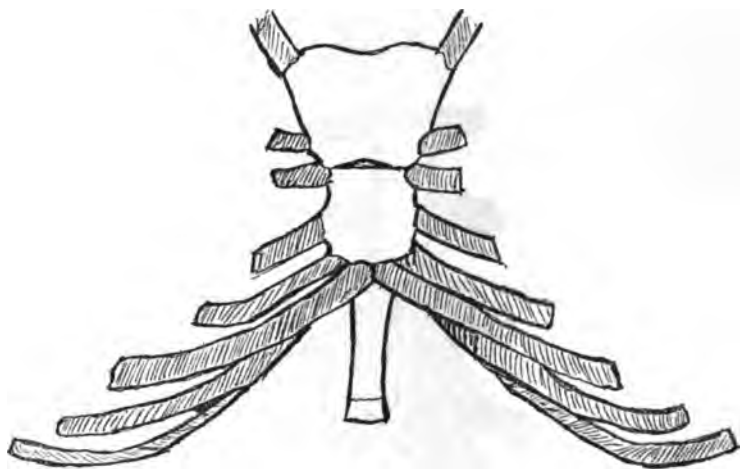


Fig. 3.

have originally divided, as it were, the manubrium from the body, *i.e.*, the first from the second sternebra. But we will immediately show, from the examination of the young gibbon's sternum, that this is not the case, and that a small sternebra is developed, but unites with the manubrium as the animal approaches maturity." Of the young one he wrote:—"The sternebrae are in an interesting period of their development. We have six separate and distinct centres of ossification, forming six sternebrae; the second uniting with the manubrium or first, and the third, fourth, and fifth uniting together will precisely give the arrangement of the adult sternum." It should be observed, however, that this does not give any evidence that

these pieces would, in point of fact, have fused in this way had the animal lived longer. I owe also to Dr Lamb's kindness a reference to Duvernoy¹ who states that in the *syndactylus* the first two pairs of ribs join the first piece of the sternum, and the third pair the first and second pieces as the second pair does in other genera.

Further researches among the writings of anatomists which I undertook yielded very little. In a French edition of Meckel's *Comparative Anatomy*, 1829, I find it stated that the first piece of the sternum of the hippopotamus gives attach-

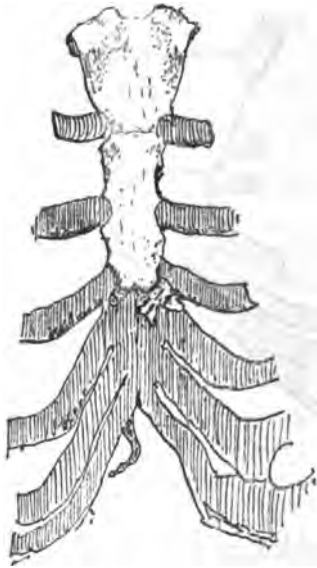


Fig. 4.

ment to three pairs of ribs, and the author continues—"It is the same with the gibbon: the first piece is relatively very large, and is in relation with the first, second, and third pairs of ribs: but then there comes another piece, a small one, situated between the third and fourth pairs of ribs, and only after that a larger piece which receives the ribs from the fourth to the seventh." It is curious to note that the progress of fusion of the different pieces of the sternum corresponds precisely with

¹ *Archives des Muséum d'Histoire Naturelle*, 1855-6, vol. viii. p. 24.

that shown in fig. 2 representing the sternum of the *Hylobates leuciscus* in the Harvard Museum, and agreeing with Dr Lamb's diagram of the *Hylobates leuciscus* and the *Hylobates lar* at Washington, but not with the *Hylobates lar* at Cambridge.

Owen¹ says briefly, that "two pairs of ribs and a part of a third pair articulate with the manubrium." It is not quite clear to me whether this statement refers to gibbons in general or only to *Hylobates leuciscus*.

Dr Giebel² writes rather vaguely that the sternum of *Hylobates syndactylus* receives on each side the first two pairs of ribs one after the other. Of the *Hylobates leuciscus* he says only that its sternum is narrower than that of the chimpanzee and ourang. He begins by saying that the species of *Hylobates* vary considerably among themselves (in the matter of the sternum).

There seems to me no doubt of the last statement, and indeed very little doubt that individual gibbons vary greatly, for in no other way can I account for the silence of many high authorities on this interesting point.

In the gorilla it sometimes happens that the first piece of the meso-sternum fuses with the manubrium, while it is distinct from the piece below it. I have seen two such cases, one in Boston and one in Cambridge, and Professor Mivart³ refers to a similar condition in the large gorilla in the British Museum.

The following observations are the only ones I know of in human anatomy. The first is by Meckel,⁴ which I owe to a reference in Humphry's *Human Skeleton*. The sternum was that of a man. He states briefly, that as usual it consisted of three pieces, only the first was relatively much larger than usual, and occupied not only the space between the first and second ribs, but that between the first and the third pair.

Sir William Turner⁵ mentions an Andaman Islander in whom the manubrium was fused with the first segment of the meso-sternum before the meso-sternum itself had completed its ossification, but this, he adds, "is quite exceptional."

¹ *Anatomy of Vertebrates*, vol. ii. p. 520.

² Bronn's *Klassen und Ordnungen des Thier-Reichs*.

³ "Axial Skeleton of the Primates," *Proc. Zool. Soc.*, 1865, p. 567.

⁴ Meckel's *Archiv*, B. iv. 1818.

⁵ *Challenger Reports*, "Human Skeletons," vol. xvi. p. 78.

In the report in this *Journal*¹ by the writer of the case of a male Western Islander, aged twenty, who had cervical ribs and peculiarities of the spine, it was stated that "the first piece of the sternum was prolonged upward, so that the articular surface for the clavicle looked almost directly outward. The manubrium and the second piece were firmly grown together, but the others were all distinct."

The most remarkable feature of the present case, is not the fact that the piece which should have been the first of the meso-sternum evidently joined the piece above much earlier than the one below it, but that the angle on the front of the sternum is transferred to the line of the third ribs, that the second ribs are displaced upward, and that all above the angle has a very plain resemblance to a manubrium. On comparing the drawing of this sternum with those of the gibbons, we see that in the latter the second ribs approach the third, so that if we suppose there were originally two segments of the sternum above the third ribs, in the case of this man, the first is the one which is dwarfed, and in the gibbon it is the second. In my opinion, however, it would be quite unwarranted to assume that there is any connection of cause and effect between the peculiar character of the breast-bone of the gibbons and that of this human one. It probably was the result of what, in want of a better word, we may call accident. It would be interesting to know whether the surmise is correct, that individual gibbons vary greatly in this respect, and to ascertain what may have been the cause of the peculiarity which their breast-bones at least frequently present.

¹ Vol. xxi. p. 543.

CONTRIBUTIONS TO THE COMPARATIVE OSTEOLOGY OF ARCTIC AND SUB-ARCTIC WATER-BIRDS. PART VII. By R. W. SHUFELDT, M.D., C.M.Z.S.

(Continued from page 187.)

Observations upon the Osteology of the Order Longipennes.

WHEN the present Part was first written, considerably over five years ago, the author had before him the classification of the *Longipennes*, as adopted by Professor Coues in his second edition of the "Key" to North American Birds, and the official *Check-List* of the American Ornithologists' Union, with its classification, had not made its appearance. It will be observed that in the former work its distinguished author grouped the Loons and Grebes together with the Auks, together in the Order *Pygopodes*, and carried the *Tubinares* as a Suborder of the Order LONGIPENNES. And such a form as *Rynchops* was considered as entitled only to subfamily distinction.

I find, as I review the Part now in hand, that when it was first written, I had proposed a scheme of classification very similar to the one now adopted by the Union in the *Check-List*, a work, as I say, that has appeared since, and during the time when I was far removed from civilised centres, and my MSS. and drawings of this Part were in the hands of the Smithsonian Institution, being reviewed by the authorities there.

Among other suggestions in this Part as it was first written, I find that I strongly urged the creation of a family to contain *Rynchops*, and attempted to show, by a comparison of larine skeletons, the propriety of that change. This has been carried out by the authors of the *Check-List*, and I am glad also to see that the two Orders, the LONGIPENNES and the TUBINARES, have also been established.

The present classification, then, divides the present order into three families, viz.:—(1) The *Stercorariidæ*; (2) the *Laridæ*; and (3) the *Rynchopidæ*.

It will be seen from the subjoined list of material which I here offer, and upon which my observations have been

Tabulated List of Material.

Specimen.	Locality.	Collector.	Smithsonian Collection, Catalogue Number.	Remarks
<i>Rynchops nigra.</i>	...	...	Not given.	Imperfect skull.
<i>Larus philadelphia.</i>	Potamac River, Washington, D.C.	H. W. Henshaw, Apr. 22, 1884.	Author's cabinet.	Complete skeleton.
<i>Larus delawarensis.</i>	Platte River, Wyo- ming.	R. W. Shufeldt, May 1880.	Author's cabinet.	Complete skeleton.
<i>Rissa tridactyla.</i>	Davis' Straits.	N. P. Scudder.	16,977	Sternum.
<i>Stercorarius pomar- inus.</i>	" "	" "	16,982	"
<i>Larus glaucus.</i>	" "	" "	16,983	"
"	" "	" "	16,984	"
<i>Rissa tridactyla pollicaris.</i>	St Paul's Island, Alaska.	H. W. Elliott.	12,519	Skeleton.
" " ♀	" "	" "	12,580	"
" " ♀	" "	" "	12,581	"
" " ♂	" "	" "	12,582	"
" " ♀	" "	" "	12,583	"
" " "	" "	" "	12,584	"
" " ♂	" "	" "	12,586	"
" " ♀	" "	" "	12,588	"
" " ♀	" "	" "	12,589	"
" " ♂	" "	" "	12,549	"
" " "	" "	" "	12,542	"
" " ♂	" "	" "	12,596	"
" " ♂	" "	" "	12,599	"
" " "	" "	" "	12,600	"
" " ♀	" "	" "	12,601	"
<i>Larus glaucus.</i>	Cumberland Island.	L. Kumlien.	16,987	"
<i>Stercorarius.</i>	...	...	13,603	Sternum.
<i>Rissa brevirostris.</i>	St Paul's Island.	H. W. Elliott.	12,556	Skeleton.
<i>Stercorarius pomar- inus.</i>	Point Barrow.	Lt. P. H. Ray.	16,730	Sternum.
<i>S. longicaudus.</i>	" "	" "	16,782	"
"	" "	" "	16,781	"
<i>S. parasiticus.</i>	Point Belcher, Arctic Ocean.	T. H. Bean.	17,002	"
" "	Port Clarence, Alaska.	" "	17,003	"
" "	Cape Lisburne.	" "	17,004	"
" "	Cape Alaska.	" "	17,005	Sternum, &c.
<i>Larus glaucus.</i>	Upennavik.	...	16,778	Skeleton.
" "	"	...	16,779	"
" "	"	...	16,777	"
<i>Rissa tridactyla.</i>	Northumberland Island.	...	16,780	"
<i>Stercorarius para- siticus.</i>	Amchitka.	W. H. Dall.	13,648	"
" "	St Paul's Island.	H. W. Elliott.	12,604	Incomplete skeleton.

made and are based, that the Terns are entirely missing from it, and the Black Skimmer (*Rynchops*) is only represented by an imperfect skull. The skeletons of these latter types were not to be found in the collections of the Smithsonian Institution at the time the material was turned over to me, and I have been unable to fill any of the deficiencies since, but trust to do so upon some future occasion.¹

I. *The Skeleton in the Gulls and Jaegers.*

A superficial examination of my material convinces me that in a number of instances we will find characters in the skeletons of some of the Gulls agreeing very closely with the corresponding characters in the skeletons of some of the Jaegers. This being the case, it is my intention, and I believe it will be an advantage, to compare in the present section the salient osteological characters as we find them in these two families, the *Laridæ* and the *Stercorariidæ*.

In *Larus glaucus* we see a good example of those Gulls that show to a marked degree many of the more typical laridine characters of the skeleton. Its skull, in particular, shows them strongly marked; and I present a side view of this part of its skeleton in fig. 1. It will be observed that all of these Gulls are typical of the group given us by Garrod, as the Schizorhinal birds, the nasals being split up their middles to a point beyond the premaxillary processes. Even in the adult Burgomaster Gull the outlines of these nasals are easily discernible, while the nasal processes of the premaxillary also show their sutural traces distinctly.

The narial apertures are very large, and carried far anteriorly, when they terminate by rounded arcs. In most Gulls and Jaegers the osseous superior mandible is more or less powerfully hooked at its extremity. Of the former before me, least so in Bonaparte's Gull. Always the dentary process is long,

¹ This statement was made early in 1885. At the present writing (March 1890) the author is enabled to say that not only are the skeletons of the Terns available to him, but there are but very few skeletons of the several hundreds of species of this country that are not. He is at present engaged upon a treatise of the osteology of the birds of the United States, which is far on the road towards completion.

narrow, and straight, while the culmen is convex and not very wide. The horizontal process of a *nasal* lies beneath the hinder moiety of this latter, while its descending bar is of uniform

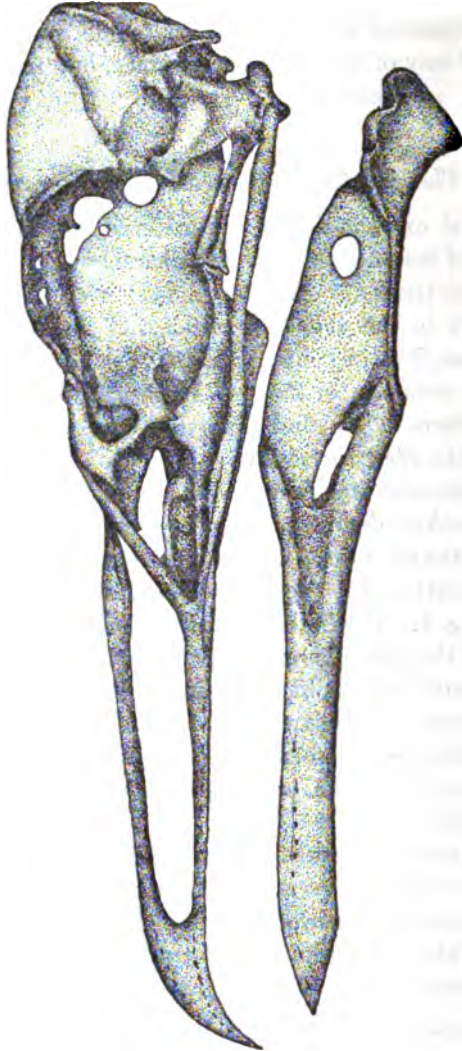


FIG. 1.—Left lateral view of the skull of *Larus glaucus*. (Specimen 16,988, Smithsonian Collection.)
Life size, by the author.

width, obliquely inclined forwards, to become expanded at its lower end before fusing with the usual bones it encounters at that terminus.

The inner margin of the body of a *lacrymal* articulates both with the frontal and the nasal; it lies chiefly in front of the *pars plana*, and develops two processes. One of these is the superior process, and its upper surface is continuous with the general superficies of the frontal region. It is directed outwards and backwards, and is somewhat perpendicularly compressed.

The other is the descending process. This is at first a thin and rather broad plate facing directly outwards; it then becomes suddenly contracted to hook backwards, and co-ossify with the lower and outer angle of the ethmoidal wing. In *Stercorarius* the upper, broad portion does not develop, and the other part is fast to the upper and outer angle of the plate referred to.

The maxillo-jugal bar is narrow, and nearly straight. It usually shows the sutures between the bones composing it to an advanced age.

An ethmoidal wing is always present, and is a thoroughly well-developed quadrilateral plate of bone. The olfactory nerve, passing through its single and open track, finds its way through a foramen at its superior margin, when it enters the rhinal chamber. In the vast majority of cases, at least one large vacuity is seen near the middle of the interorbital septum, though one of the *L. glaucus* before me has this osseous partition entire. Each optic foramen, as well as the smaller one to its outer side, in all the specimens, is entire, though, in the case of the first mentioned, larger than the nerve to which it gives egress.

This condition is not found to exist in the foramen for the passage of the olfactory from the brain case, as that is much larger than its purpose demands, and sometimes of a jagged outline.

Chief among the notable features of a Gull's *quadrato* bone is the prominent way in which its lateral portion is produced outwardly to meet the *quadrato-jugal*. The Jaegers show this character unusually well.

For the rest, the bone is large, being in the Burgomaster above the average, in this particular, for the size of the skull. Among the Jaegers its orbital process is short and very wide; while in the *Laridae* this part is longer, and its extremity expanded. The squamosal and sphenotic processes jut out pro-

minently at their usual sites, and the included valley between them for the passage of the digastric muscle is deep and uniformly concave.

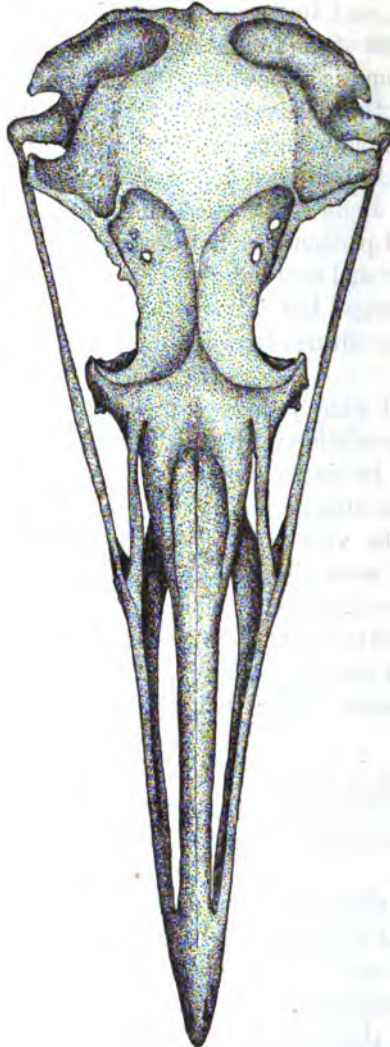


FIG. 2.—Superior view of skull of *Larus glaucus*, mandible removed. (Specimen 16,988, Smithsonian Collection.) Life size, by the author.

From a superior view, the general features of the skull in both Gulls and Jaegers are very much the same, but I may add,

very different indeed from those presented us in the skull of *Rynchops*. I believe that a sufficient number of figures, either in the plates or cuts, have been offered to show how very much alike the species of these two families are in this particular. *Stercorarius* comes right along in the same series, exhibiting but a few unimportant differences which will be mentioned as we proceed. We have already called attention to the appearance of the superior mandible, the nasals, the hinder ends of the premaxillary, and the distinctness with which these may still be seen in the concave cranio-facial region of the adult Gull. Just posterior to this there is a smooth frontal area with the prominent lacrymals extending from either side. Then come the broad and rather shallow concavities for the nasal glands. These are perforated by more or fewer foramina, and they meet for some distance in the median line.

Now the parietal region varies in the different genera, a variance depending principally upon the form and size of these supra-orbital depressions, the crotaphyte fossæ, and the general inclination of the surface. As an example as to how the first two mentioned factors may effect this, no two skulls could show it better than those presented in figs. 3 and 4, being the superior views of these parts in *Rissa tridactyla* and *R. brevirostris*.

The cranial vault is globular and smooth in Bonaparte's Gull, equally so, though proportionately larger in the parasitic Jaeger. This latter bird has its crotaphyte fossæ entirely lateral, and feebly impressed—hardly of sufficient depth to attract attention in the skull in my hand.

Upon an *inferior view* of the skull in *L. glaucus* we find the anterior extremities of the palatines very narrow and very long. Where they overlie the anterior parts of the maxillo-palatines, each is a little dilated; but beyond this, they contract and are closely applied to the inferior surfaces of the dentary processes of the premaxillary, being internal to them, as far as these latter extend in that direction. The osseous tomia are slightly raised and sharp.

Each maxillo-palatine fuses by its anterior pedicle with the usual bones, the nasal, the palatine, the maxillary from which

it is developed, and dentary process of premaxillary. It is a thin concave-convex plate, with its convex side towards the median plane, where it is separated from the fellow of the opposite side, and the vomer, by an open cleft or interval. The form of this maxillo-palatine varies but slightly among the *Laridæ*, and usually its outer concave aspect shows a few trabeculæ thrown out as tie-beams across it.

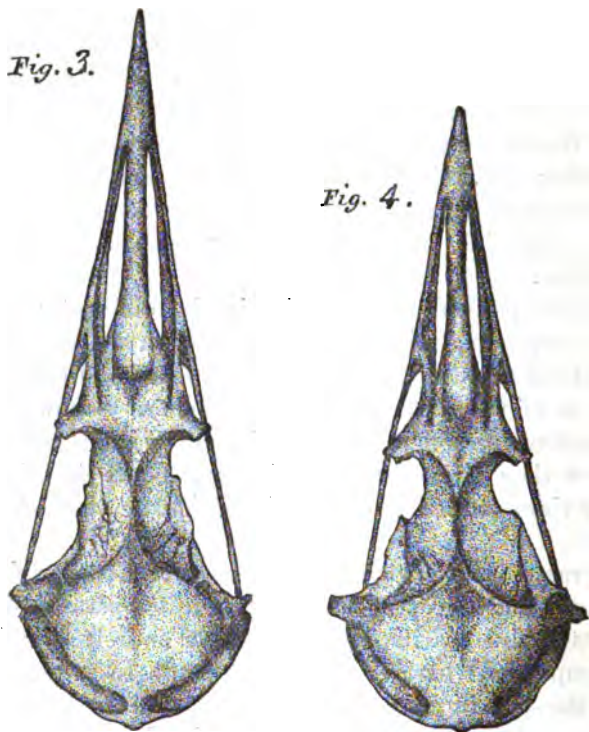


FIG. 3.—Superior view of skull of *Rissa tridactyla*. (Specimen 12,542, Smithsonian Collection.)

FIG. 4.—Same view of skull of *Rissa brevirostris*. (Specimen 12,556, Smithsonian Collection.) Both life size, with mandibles removed, by the author.

In this Burgomaster Gull the vomer is just as much one of the free bones of the skull as a pterygoid is. Behind, its limbs grasp the rostrum, and abut against the ascending process of a palatine on either side. Above, it is excavated for its entire length, and in this channel the projecting rostral apex is lodged for the hinder third of the groove. Below, the vomer is longi-

tudinally carinated, which carination is carried beyond the bone in front as a sharp spine, to be seen just between the anterior endings of the maxillo-palatines.

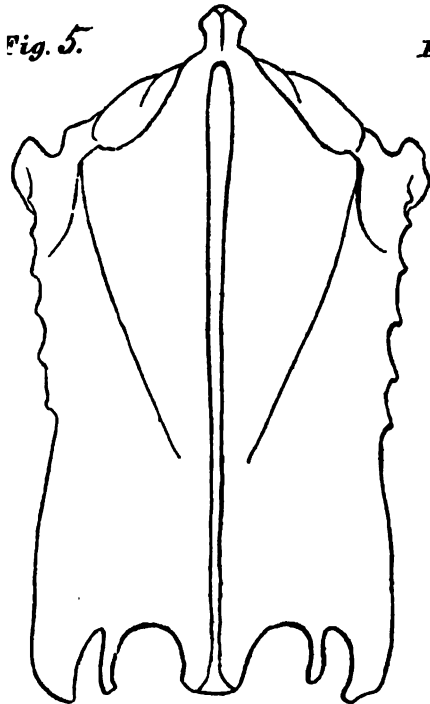


Fig. 6.

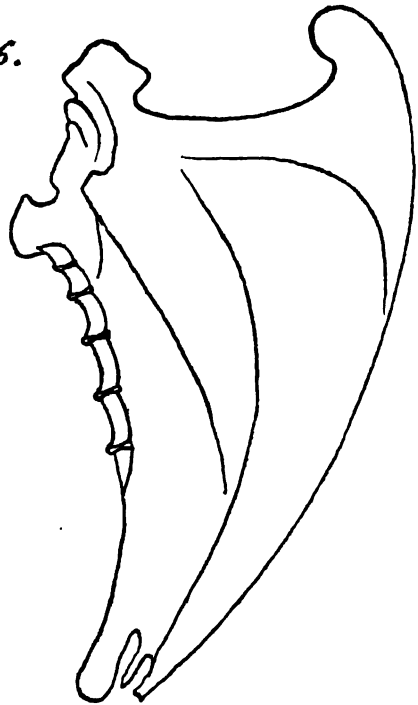


FIG. 5.—Outline of sternum of *Larus glaucus*, adult; pectoral view. (Specimen 16,988, Smithsonian Collection.)

FIG. 6.—Right lateral view of the same bone. Both figures life size, by the author.

The *pterygoids* are straight-shafted bones, with the usual modified anterior and posterior ends to meet the quadrates and palatines. A prominent longitudinal crest always occupies the length of the upper border of the shaft, and when the bones are articulated, the angle between them behind is a small one. Assisted by the juxta-opposed palatine heads they have on the upper side of their anterior ends the channel for the spheroidal rostrum, the four heads meeting to form it, as described for the *Pygopodes* and others.

The occipital condyle is small, hemispherical, and sessile, and

the plane of the periphery of the rather large foramen magnum makes an angle with the plane of the basis cranii of about 20° in Bonaparte's Gull and 40° in *L. glaucus*, these apertures expressing the limits either way.

Gulls and their allies have a characteristic posterior aspect to their skulls. This is well shown in the several figures of Plate II. Part I., where I have compared this view with the same parts in a number of other birds in which they differ, and where the contrast constituted an advantageous comparison.

From this point we are enabled to see in *L. glaucus* the smooth area at the vault of the cranium, with its shallow, longitudinal groove, flanked on either side by the spreading post-frontal wings. Lower down, the median strip, here about the same as in *L. delawarensis*, between the deep crotaphyte fossæ is observed; then comes a well-defined occipital area which, roughly speaking, has arcs of circles for its upper and lower borders, concavities downwards, and straight lines for the sides, which, if produced downwards, would meet at a point without the skull, and a short distance below the quadrates. This area contains the occipital prominence in the middle, surmounts the foramen magnum, and its outer limits form the hinder wings for the auricular apertures. Most of the foramina for the egress of the cranial nerves, and other openings, may be plainly seen upon this view, whereas in many other birds these are in the horizontal plane.

We may here give some idea of the comparatively large size of the quadrate bones and their produced lateral parts. They are seen to be thoroughly pneumatic, and a considerable foramen is a conspicuous feature of the posterior aspect of each at the middle of the shaft. Turning now to the *mandible* in these birds, we find the symphysis is short, excavated above, while below it is truncated from before, backwards, and convex.

In *L. glaucus*, which very well typifies the pattern of this bone for the Gulls generally, we find that the anterior moiety of either ramus is less than half the width of the hinder half. Its superior and inferior borders are parallel to each other, the tomia of the former being cultrate, and in the latter rounded. As a whole, these ramal sides are erect, being smooth behind, and rather convex in the perpendicular direction in front.

Upon an inner aspect we find the surangular developing the same process as is seen in the Albatross, but here in the Gull neither it nor the other mandibular elements quite succeed in completely closing in the ramal vacuity (fig. 1). Posterior to this the surangular is pierced by a large foramen, which is constant for this family, though a spicula of bone divides it in two in the Common American Gull.

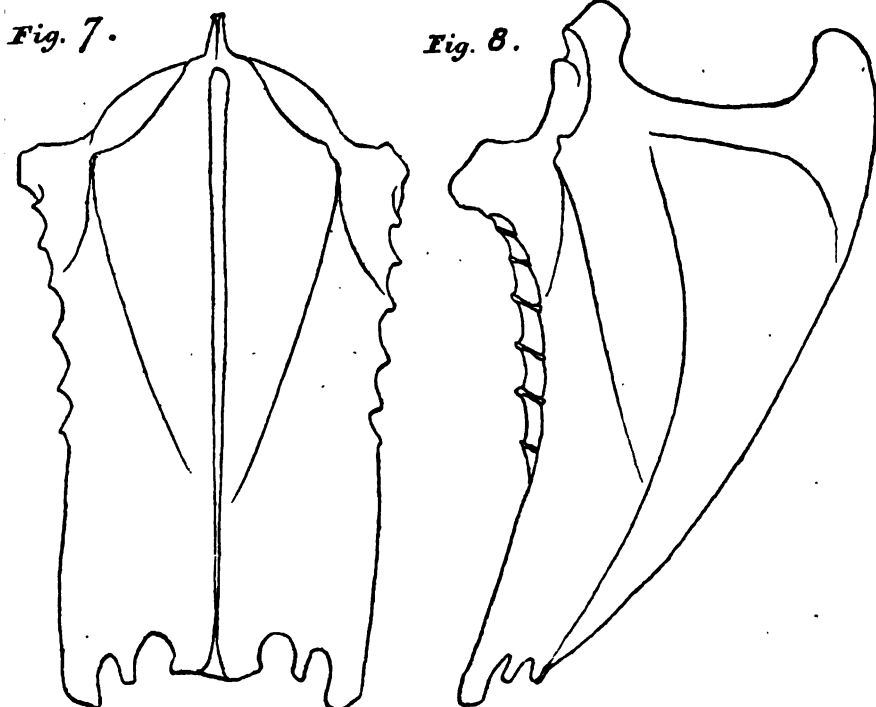


FIG. 7.—Outline of sternum of *Larus glaucus*, "bird of the year;" pectoral view. (Specimen 16,777, Smithsonian Collection.)

FIG. 8.—Right lateral view of the same bone. Both figures life size, by the author.

In the Jaegers it is absent, a dimple merely indicating its position. The coronoid process is to the rear of this on the upper border, but is very feebly developed.

Among all the Gulls an articular end of the mandible has its posterior surface nearly at right angles with the long axis of the bone, being somewhat concave, and bounded by a subcircular

raised border. The centre of an articular cup is deep and perforated by the pneumatic foramen; in the Jaegers, however, this latter is at the apex of the "inturned process," as among most birds.

The Burgomaster has these inturned ends of the articular extremities rather stumpy, and their apices are pointed directly upwards, being smooth at the points where they come in contact with the prominences at the postero-external angles of the basi-temporal. In *Rynchops* a direct articulation takes place at this point.

L. delawarensis presents me with a perfect *hyoidean apparatus* among my specimens, and one that seems to include all the characters of the skeleton of these arches among adult individuals of the family *Laridæ*, as well as among the *Stercorariidæ*.

In it we observe that only the posteriorly moiety of the glosso-hyal ossifies, while anteriorly it is continued in cartilage.

The cerato-hyals are co-ossified with the glosso-hyal, and continuous with it, a fenestra being seen just beyond them in the median line.

First and second basi-branchials also co-ossify, the former having much the same shape as we see it in the Albatrosses, the latter being a straight spine directed backwards from the former in the median line. This osseous portion of the second basi-branchial, however, is produced fully two-thirds as far again in a cartilaginous rod of the same calibre in the *Laridæ*. Cerato-branchials are long and slender, and articulate as in birds generally, being essentially of the same type as we found them in the *Alcidæ*—*Alca*, for example. The epibranchials are mostly in cartilage in this specimen, only a fraction of their upturned ends taking on ossification.

Of the remainder of the Axial Skeleton in the Laridæ and Stercorariidæ.

In the remainder of the axial skeleton the Gulls and Jaegers are even more alike than we found them to be in the skeletons of their heads. The number of their vertebræ agree, and the

arrangement of their ribs are upon the same plan. Indeed, this may almost be said, without raising an exception, of their pelvis, sternum, and shoulder-girdles. My description, then, of these parts may be taken as applying to both families, and such trivial exceptions as exist will be pointed out as we proceed.

The vertebral column consists of forty-one vertebræ and a pygostyle. Those in the neck, as distinguished from the corresponding segments in a Razor-bill Auk, may be said to be generally longer, and their post- and pre-zygapophyses stouter, and less inclined to spread laterally. Moreover, they are pneumatic in the Gull, which is not the case in the Auk.

The cup of the *atlas* is not perforated in any of the Gulls or Jaegers, and occasionally its neural arch is very broad, as in *Rissa*. Axis vertebra has both neural spine and hypapophysis, while the pre- and post-zygapophyses in the third and fourth segments are united laterally by an osseous lamina, perforated on either side, to a greater or less extent, by a foramen. The neural spine is absent for the first time in the sixth vertebra, and it is in this one too that the hypapophysial canal terminates above, it being present also in the seventh, eighth, and ninth. After that, a low hypapophysis again makes its appearance, to become bifid and thoroughly sessile in the fourteenth to the seventeenth vertebra inclusive, it being entirely absent in the remainder of the dorsal series. Both Jaegers and Gulls have the pleurapophyses free, as a minute rib, for the first time in the fourteenth vertebra, but they merely hang from the under side of the outer extremity of either transverse process as a diminutive rod of bone. These show very well in the skeleton of *L. philadelphia* from the excellent specimen of that Gull presented me by Henshaw.

The fifteenth vertebra supports a moderately well-developed pair of ribs that are without epipleural appendages, and have free extremities. A low neural crest again makes its appearance here, but it is as yet hardly comparable with that process of a true dorsal segment.

From the sixteenth to the twentieth vertebræ inclusive, we have the typical dorsal series. These are all freely movable upon one another, and all have vertebral ribs meeting costal ribs below. Their transverse processes are broad, and stand

directly out from the centre of the several segments ; while their extremities bear long interlacing metapophyses. The quadriform and interlocked neural plates of this series are also restricted in their motion upon one another, by the numerous osseous spiculæ which cross and recross each other among them.

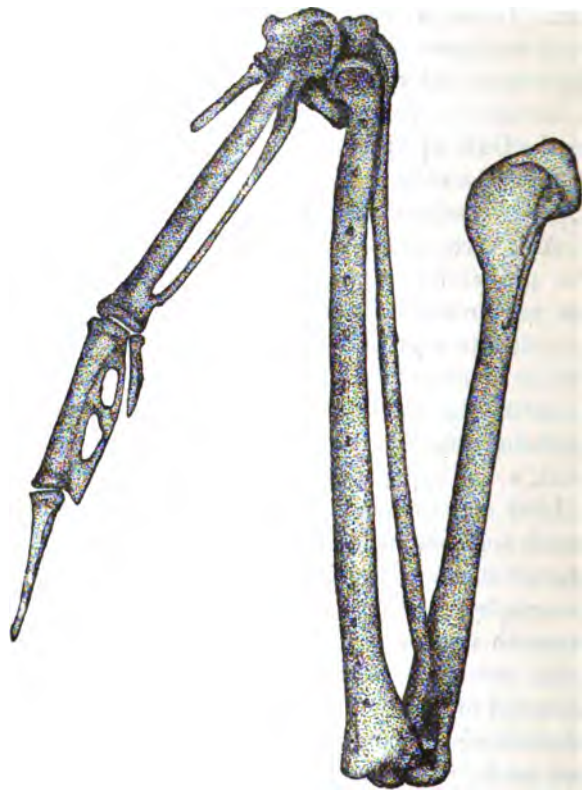


FIG. 9.—Left pectoral extremity of *Rissa tridactyla*. (Specimen 12,542, Smithsonian Collection.) Life size, by the author.

The centra of the vertebræ are characterised by being much compressed transversely, and their lateral aspects marked by pit-like concavities, one of regular outline monopolising either side, below the diapophysis. They are all pneumatic.

Five pairs of ribs coming from these vertebræ have nothing peculiar about them ; they support long epipleural appendages

which anchylose with the hinder margins of their bodies. In *Rissa*, one of the appendages in mid-series overlaps two ribs behind it; not so in *L. delawarensis* and *Stercorarius*, where only the succeeding rib is overlapped (fig. 13).

Two pairs of ribs spring from the pelvis, the hæmapophyses of the last not reaching the costal borders of the sternum. The last pair may anchylose above with the ilia and the twenty-second vertebra from which they really come; they never bear epipleural appendages (*Rissa*).

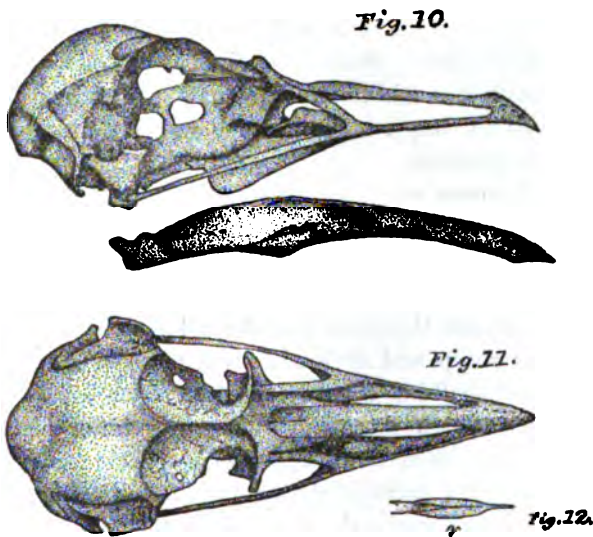


FIG. 10.—Right lateral view of skull of *Stercorarius parasiticus*.

FIG. 11.—The same specimen from above, mandible removed.

FIG. 12.—Its vomer (v), viewed from below. All these figures, life size, by the author, from specimen 13,648, Smithsonian Collection.

These latter processes may or may not appear on the other pair, or there may be one on one side and not on the other, a character of no great moment in any event.

This arrangement gives us six pairs of costal ribs that articulate with the sternal borders (fig. 13). As a rule, in the vast majority of cases, from the twenty-first to the thirty-fourth vertebra inclusive, are firmly anchylosed together to form the pelvic sacrum. Of these the twenty-second, third, fourth, fifth,

and perhaps sixth may throw out apophysial abutments against the under sides of the ilia ; then follows an interval where only the superior apophyses are developed, best seen on the dorsum.

The *thirtieth vertebra* of the pelvic sacrum in these Gulls is quite a remarkable one, as both its pleur- and parapophyses are very long, and strong traces reaching across the pelvic basin to points behind the cotyloid cavities, where ridges are developed to receive their expanded and co-ossified ends ; they thus act as powerful supports to these parts.

The next four anchylosed vertebræ of the pelvis, as we proceed backwards, become more and more like the free caudal ones in general appearance. Sometimes the last one of these may be free, and thus add an additional segment to the coccygeal series, or if this does not happen, the last one may not unite with the pygostyle (*L. glaucus*).

Foraminal spaces are very perfect between the apophyses of these sacral vertebræ, more particularly in the Jaegers, where they form two regular rows down the dorsum of the pelvis, with a few scattered ones on either side.

So numerous are the figures that we have presented of the pelves of this group, and as these convey more to us than words alone can do, I shall but briefly notice the characteristic points.

Generally, in both these subfamilies, the inner margins of the anterior portions of the ilia fuse with the thickened neural crest of the leading sacral vertebræ, forming ilio-neural canals. There may be an occasional exception to this, while in others the union is very perfect.

The anterior iliac borders are always emarginated, but vary a little in outline, not only for the different genera, but for the different ages in the same species. A good example of this is seen in *L. glaucus* (to be figured in Part VIII.).

The preacetabular surface of the ilia are concave, and this entire area rather exceeds in extent the post-acetabular.

The inner iliac margins of the hinder portion of the pelvis unite perfectly throughout with the margins of the lozenge-shaped pelvic sacrum.

L. glaucus has the posterior parts of this latter gradually depressed from before, backwards, below the general post-acetabular surface.

Behind, the pelvic border is deeply concave, the ilium, ischium, and post-pubis extending backward in regular graduated sequence. Upon lateral view we notice a large, subelliptical ischiac foramen, and a shallow notch between the ilium and

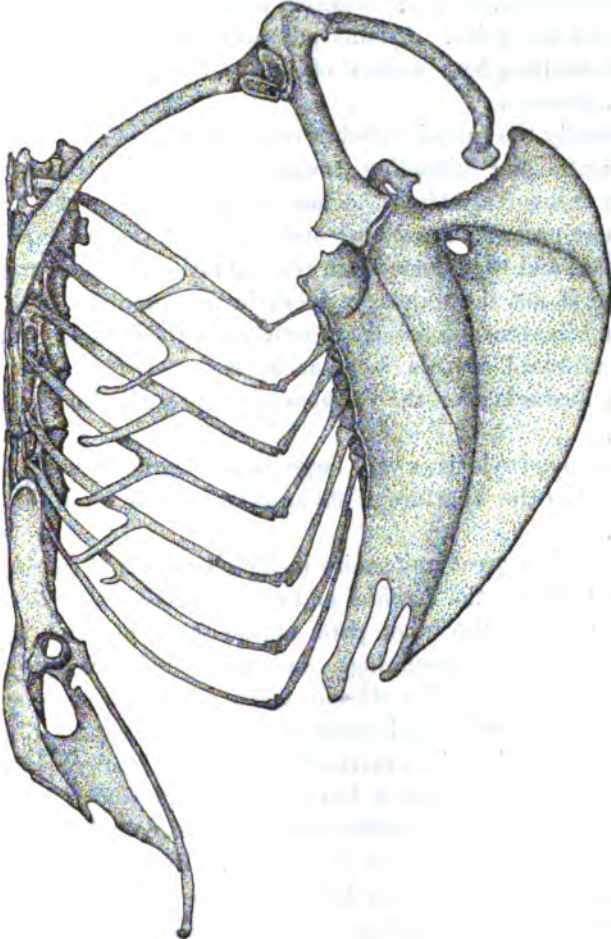


FIG. 13.—Skeleton of the trunk, *Stercorarius parasiticus*. (Specimen 13,648, Smithsonian Collection.) Life size, by the author.

ischium behind. The obturator foramen opens into the obturator space, the latter being very large and spindle-formed in these birds.

In *Rissa* and *Stercorarius* the end of the ischium dilates

into a foot-shaped expansion, the lower border of which is ligamentously attached to the post-pubic bar. This is more extensive in the former than it is in the Jaeger. Sometimes this is the case in Bonaparte's Gull, but in all the others, in the dried skeleton, no such condition exists, the ischium terminating in a free point. A faint propubis may be seen in either of these families, best marked of all in the specimens before me, in *L. glaucus*.

Usually the caudal vertebræ runs this way—the first two have horizontal and spreading transverse processes, the segments more or less resembling the last uro-sacra, then the next two of these processes are shorter and depressed, they then gradually increase and then decrease in regular ratio, the sixth being one of the, if not the widest, vertebra in the column. In the last, these transverse processes are nearly absorbed. More or fewer of the ultimate caudals have anchylosed chevron bones, which hook forwards over the vertebra that precedes them in each case.

The pygostyle is a very large parallelogramic bone, usually pierced in the aperture of its anterior-inferior angle by a foramen.

There is a great uniformity in the characters of the *shoulder-girdle* among the *Laridæ* and *Stercorariidæ* that is quite in keeping with the other parts of the trunk skeleton which we have just been examining. An extraordinary cropping out of the characters of the *Alcidæ* takes place in each one of the bones of this arch that is interesting in the extreme. *L. glaucus* shows all of these in a marked degree. In the *furcula* we have the elongated clavicular head, with the projecting facet at its outer aspect, for articulation with the coracoid, both developed fully as well as we find it in *Alca*. Below these clavicular heads the limbs of this broad U-shaped arch are somewhat slender, of uniform calibre, curved gently backwards, and support, at the thickened portion below, a small quadrate hypocleidium. As in the *Alcidæ*, the rather tuberos head of a *coracoid* hooks forward to make its articulation with the facet described as existing on the outer side of the clavicular head. The shaft is subcylindrical and well dilated in the usual way at its sternal extremity. At the lower lateral margin externally

we observe the laminated and hooked process, so prominent among the Auks and equally well developed here.

The upper border of the scapular process of the coracoid barely accommodates the head of the shoulder-blade when the two bones are articulated as in life; while below it is pierced by the foramen so often mentioned as there existing in allied forms. Further, this process is so curled to the front that it presents no inconsiderable surface to the mesial plane, and a long free border anteriorly. One of the most remarkable characters of the coracoid among the Gulls, and it is developed to the fullest extent in this Burgomaster, is the concavity that monopolises the entire interior of the head of this otherwise massive-appearing extremity. This very extensive and deep fossa has its entrance facing directly downwards, and overhanging the tendinal canal on the mesial aspect, the aperture being nearly as deep from before backwards as the coracoid head is. In other words, the ponderous-looking head of the coracoid in this Gull is a mere shell, and quite thin in some places; so the light may easily be seen through it. No such condition as this obtains either with the *Urinatoridæ* or with the *Alcidæ*.

A *scapula* is of good size, moderately decurved, and of uniform width throughout. Its hinder extremity is truncate, and its head much compressed in the vertical direction. The glenoid cavity is of fair size and formed in the ordinary way, this latter element offering rather a larger share of the articular surface than usual.

In the Jaeger the posterior ends of the clavicular heads are dilated in a perpendicular direction, so that, when the arch is normally articulated, they are wedged in between the coracoidal head and the scapula, making a very firm joint. When the entire arch is articulated, as in life, the scapular process of a coracoid may, in some instances, also reach the clavicle—indeed, it seems to be quite the rule for it to do so. The hypocleidium clears the carinal angle below by quite an interval, and the inner angles of the sternal extremities of the coracoids usually meet behind the manubrial base.

The pelvic arch, among this group of birds, is a non-pneumatic one.

Of the Sternum.—The figure formed by the borders of the

sternal body in all these birds is invariably a parallelogram. It is wide and not so long among the Gulls, whereas among the Jaegers it is the rule to have the width, from one costal process to the other, a little less than half the length.

The general form of the bone in either family is characteristic, having a peculiar style of its own not to be confused with that of any of the other birds we have thus far investigated.

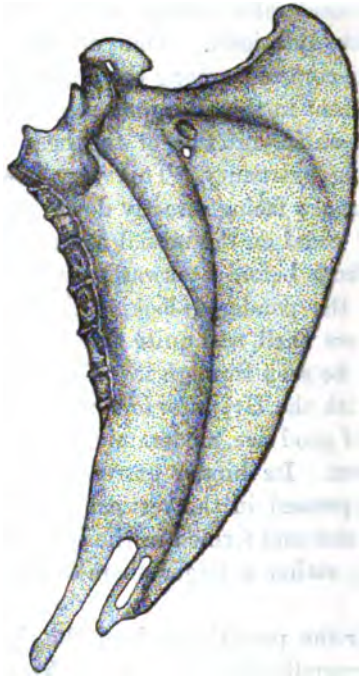


FIG. 14.—Sternum of *Stercorarius pomarinus*, right lateral view. Life-size, by the author, from specimen 12,605, Smithsonian Collection.

Upon the anterior border the costal grooves are deep, generally concave from above, downwards; convex in the opposite direction. Their mesial extremities turn inward to meet behind the posterior manubrial base. They are of nearly an equal width throughout, their external extremities terminating on either side in a shallow depression which is situated rather in front of the base of the costal process.

The manubrium is large and wedge-shaped, the thin edge being directed downwards and forwards. Among the *Ster-*

corariidæ it is perforated by a foramen at the middle, which passes directly through from side to side.

In the Jaegers the costal processes, although they have broad bases, are low and truncate above; they are better defined in the Gulls, where, as in *L. glaucus*, their summits are finished off with an expanded portion. Each costal border faces upwards and outwards, and in the vast majority of cases always supports six hæmapophysial facets. These are largest in the middle of the series, and regularly decrease in size both ways.

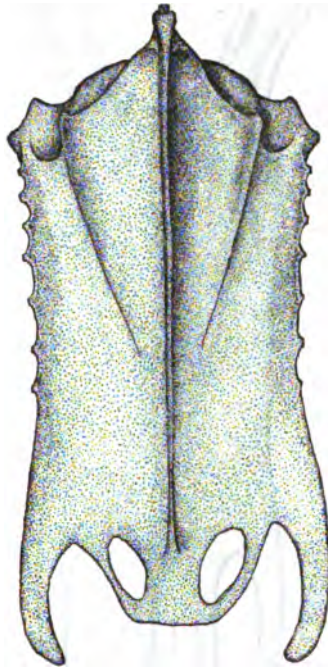


FIG. 15.—Pectoral aspect of sternum of *Stercorarius pomarinus*. (Specimen 12,605, Smithsonian Collection.) Life size.

In *L. glaucus* they are prominently raised on their transverse bases, and may have a pneumatic foramen or so in the intervening spaces. However this may be, in the Burgomaster (*L. glaucus*) the first two anterior ones of these spaces are deeper than they are wide, a condition I have never noticed in birds before. The *Stercorariidæ* usually have the regular pneumatic foramina in these spaces.

A lateral border posterior to this costal portion is thin and sharp, being carried directly backward to form the outer margin of the external xiphoidal process. Among the Gulls, the xiphoidal border of the sternum exhibits two notches on either side of the median line. Of these, the outer, and usually smaller, pair (except) *Rissa* give rise to the larger and rather longer

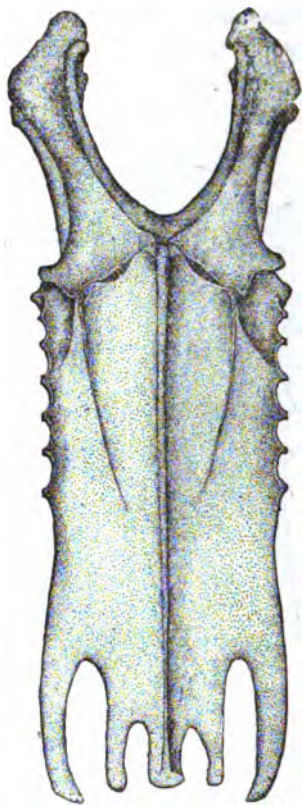


FIG. 16.—Sternum and shoulder girdle of *Stercorarius longicaudus*, pectoral aspect. Life size, by the author, from specimen 1659, Smithsonian Collection.

pair of lateral xiphoidal processes. The inner notches complete the inner and smaller pair of processes, while the median process, which supports the end of the keel beneath, is larger than any of these.

L. glaucus has a sternum that varies with the age of the bird,

being narrower in the young bird of the year, and less robust. Moreover, the notches have nothing like the depth they have in a fully-matured specimen (figs. 5 to 7).

This pattern of the xiphoidal extremity of the Gulls answers very well for *Stercorarius longicaudus* among the *Stercorariidæ*, except in this latter bird these outer notches are comparatively very much deeper, and the lateral processes much longer, with their extremities occasionally turned inwards. The inner pair of notches are in, as it were, a mid-xiphoidal and square process formed by the larger notches at the sides; this condition is well shown in fig. 14. Now, in *S.*

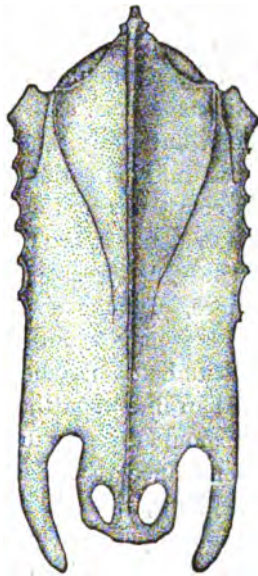


FIG. 17.—Pectoral aspect of the sternum of *Stercorarius parasiticus*. Life-size, by the author, from specimen 12,604 of the Smithsonian Collection.

pomarinus and *S. parasiticus*, these inner and smaller notches are reduced to foramina, which, in some specimens of these two latter Jaegers, may disappear entirely, and thus leave the sternum a two-notched one. So far as I know, this condition here may depend entirely upon age, but in any event should be borne in mind when we wish to compare such bones with others. Moreover, this fact should be given its due weight in comparing, and perhaps restoring fossil forms of birds, presuming,

as I do, that like changes were in operation during geologic time.

The body of the sternum is profoundly concave upon thoracic aspect, and correspondingly convex on the pectoral side. Upon this latter the chief muscular line runs from the lip of bone opposite the outer end of the coracoidal groove to a point behind the middle of the carina.

The keel is ample, and occupies the median line of the sternal body for its entire length, being produced upon the midxiphoidal process. Its angle in front is prominently produced and rounded, being more or less curled upwards in the different species. This form gives to the anterior carinal border a concave outline forwards. Sometimes this is much flattened, and among the Jaegers may be pierced by a pneumatic foramen. In these latter birds, too, a hole is sometimes seen in the sternal keel, or perhaps a group of them, anteriorly, and close to the body of the bone. All have the inferior carinal margin composed of one long, gentle convex curve, directed downwards.

The chief pneumatic foramen is in the median line, just within the anterior border on the superior aspect of the body. In the Gulls it is usually square, of some size, sharply defined, and single; but in the Jaegers it may be multiple, or even, as in one specimen of *S. parasiticus* before me, being an irregular group extending down the median line upon the same aspect.

While examining the shoulder-girdle in these two subfamilies, we saw its marked resemblance to the shoulder-girdle of the Auks and Guillemots. Now, this similitude is not quite so striking when we come to compare the sterna of the two groups. Still, I think, that we cannot fail to trace, even here, the strongest resemblances among these bones. The relationship, it seems to me, is much closer than that existing between the *Lauridæ* and *Urinatoridæ*. I mean, of course, in so far as the sterna of these two latter groups are concerned. Of their kinship, otherwise, we will have something to say in the next Part.

VARIATIONS OF THE EXTERNAL PTERYGOID
MUSCLE. By JOHN POLAND, *late Senior Demonstrator
of Anatomy, Guy's Hospital.*

MANY instances of variation in the arrangement of the fibres of this muscle having come under my notice in the dissecting room at Guy's Hospital during the past two sessions, I thought a record of my notes might be interesting, especially as I am unable to find any description of one variety frequently met with. 133 subjects were dissected during that period.

Pterygoideus Proprius (Henle).—Several forms of this muscle were seen. I believe with Shepherd (*Jour. Anat. and Phys.*, vol. xv. p. 293) that this muscle is very often present, but destroyed by careless dissectors in detaching the coronoid process of the lower jaw and temporal muscle, with the deeper tendinous fibres of which it is frequently blended. In each case the fibres, mostly tendinous in structure, were attached above to the pterygoid ridge on the great wing of the sphenoid at its anterior part, and to the portion of the great wing below this, blending with the origin of the upper head of the external pterygoid muscle from the same surface. These fibres passed vertically downwards, and were attached below to the lower margin and a small portion of the external surface of the external pterygoid plate. From the deep aspect of these tendinous fibres, as they passed over the external pterygoid muscle, some of the normal horizontal fibres of the external pterygoid arose as described by Wagstaffe (*Jour. Anat. and Phys.*, vol. v. p. 282). In one instance, similar to that figured by Wagstaffe (*loc. cit.*, p. 283, Case 2), this muscle was very largely developed, being $\frac{3}{4}$ inch in breadth, and its muscular fibres were connected above with the fibres of the temporal muscle, and largely below with the anterior fibres of the external pterygoid. In the same subject, on the opposite side, there was a small pterigo-spinosus muscle but no *pterygoideus proprius*.

In none of my cases have I found any attachment to the tuberosity of the palate or superior maxillary bones of which

Professor Macalister has seen many examples ("Catalogue of Muscular Variations," *Trans. Irish Acad.*, vol. xxv. 1872), to the pterygo-maxillary ligament, to the inferior maxilla, or to the buccinator muscle. Nor was the origin of the external pterygoid from the tuberosity of the superior maxilla or palate bone absent in any of the cases. In some instances the upper head of this muscle was noticed to be small and tendinous. A common condition, alluded to above, was found to be the blending of the deep aspect of the temporal tendon with the external pterygoid. Shepherd (*loc. cit., supra*) mentions a case in which the pterygoideus proprius muscle was chiefly connected with this part of the temporal muscle, but I have met with no instance of this variety.

Pterygo-spinosus (Thane).—This musculo-tendinous slip is said by Macalister to be often found replacing the pterygo-spinous ligament (Civinini) (*loc. cit., supra*). He also mentions cases recorded by Schmidt and Theile.

Of the twelve different forms of this muscle which I observed, many had their anterior attachment to the tooth-like process situate on the posterior edge of the external pterygoid plate between the two pterygoid muscles, and evidently replaced the lower fibres of the pterygo-spinous ligament. In others the whole of the fibres of the ligament or its bony representative were also present.

In these latter cases, however, the upper attachment of the muscle usually differed considerably from that given by Thane, viz., to the spine of the sphenoid, and was associated in many instances with a more or less abnormal arrangement of the false internal lateral ligament (spheno-mandibular).

Thus:—In one case (1) a small muscle arose from the Glasserian fissure as well as from the lower aspect of the spine of the sphenoid, and passed downwards beneath the inferior maxillary nerve and middle meningeal artery to the posterior margin of the external pterygoid plate above its middle. The false internal lateral ligament was represented by a strong band of fascia extending from the Glasserian fissure to the posterior border of the lower jaw behind the inferior dental canal. A delicate layer of fascia was found in the normal position of this

ligament. The middle meningeal artery passed up in this case through the foramen ovale. In another case (2) there was a well-marked slip of muscle attached to the spine of the sphenoid and to the posterior margin of the external pterygoid plate. The false internal lateral ligament was connected to the spine of the sphenoid above, and below to the posterior border and inner aspect of the lower jaw, immediately behind the dental foramen. This muscle was absent, and the ligament normal on the opposite side.

In case 3, on the body of a negro, aged 26, a small muscle existed on the right side, tendinous at either attachment, viz. in front to the posterior border of the external pterygoid plate close to the root and behind to the spine of the sphenoid, and to the upper part of the false internal lateral ligament. This fascia was ill developed between its usual attachments, but an extension backwards from it to the Glasserian fissure was strong and tough, and joined below to the inner surface and posterior margin of the inferior maxilla. This muscle was absent on the opposite side.

Case 4. On the right side of a powerful muscular subject (a sailor) a considerable sized muscle, $\frac{1}{2}$ inch broad, partly tendinous, especially anteriorly, and partly muscular, arose from the spine of the sphenoid, and thence extended backwards to the inner side of the glenoid cavity in a line with the false internal lateral ligament on the inner side of the capsule of the articulation of the lower jaw. This fascial ligament was not at all attached to the spine of the sphenoid, but behind (where it was very broad and strong) to the inner side of the glenoid cavity, the auriculo-temporal nerve being interposed between it and the capsule. Its lower attachments were normal. The various structures on the left side were normal.

Case 5. A muscular male subject. On the left side a muscle with similar attachments to the last, but smaller in size. The internal lateral ligament was also similar. On the right side a pterygoideus proprius muscle was present (see above).

Case 6. A muscle similar in attachments to No. 4, though smaller. False internal lateral ligament normal in its lower attachment, absent above from spine of sphenoid, but prolonged backwards to the Glasserian fissure.

II. Another variety of form was met with, in which the upper attachment to the spine of the sphenoid was absent; the upper fibres of the muscle in this series being attached to the Glasserian fissure and blended with a more or less irregular internal lateral ligament. The lower fibres to the posterior border of the external pterygoid plate, in one case to the whole extent of this margin:—

Case 1. On the left side of a male subject a somewhat large bundle of muscular fibres sprang from the Glasserian fissure internal to the attachment of the capsule of the temporo-maxillary articulation, and was blended with the false internal lateral ligament, which was attached almost as far forwards as the spine of the sphenoid. This muscle was inserted below into the posterior margin of the external pterygoid plate. Pterygo-spinous ligament well developed.

Case 2. A muscular slip $\frac{1}{2}$ inch broad, on the inner aspect of the temporo-maxillary articulation, was connected behind with the Glasserian fissure, and intimately united with a dense fascial extension backwards and inwards of the false internal lateral ligament along this fissure. This fascia was attached below to the lower jaw behind the dental canal to the limit of the posterior margin of the bone. The normal ligament was represented by a layer of delicate fascia. Passing in a sling-like manner the fibres of this muscle became aponeurotic; a few were incorporated with the outer aspect of the tendinous fibres of the internal pterygoid muscle; the greater part, however, passed to the prominent tip and posterior margin of an unusually large external pterygoid plate. The internal pterygoid muscle arose from the tuberosity of the superior maxilla, and the upper head of the external pterygoid muscle was small and tendinous. A little muscle with similar connections existed on the opposite side.

Case 3. On the left side of a muscular male subject, a musculo-tendinous layer, $\frac{3}{4}$ inch in breadth, connected behind with the Glasserian fissure and anterior part of the internal lateral ligament, in front to the whole of the posterior border and outer aspect of the internal pterygoid muscle. Pterygo-spinous muscle also present. No abnormality on the right side.

Case 4. A similar muscle to the preceding, though smaller;

the only difference being that its anterior extremity was almost entirely united with the tendinous fibres of the internal pterygoid muscle.

Lastly, there were two cases in which this peculiar muscle was connected behind solely with the so-called internal lateral ligament, one in front with the external pterygoid plate, and the other with this as well as with the internal pterygoid muscle. This muscle might appropriately be termed the PTERYGO-FASCIALIS MUSCLE.

Case 1. In a male subject, aged 38, a sheet ($\frac{1}{2}$ inch broad) of musculo-tendinous fibres passed from the internal lateral ligament obliquely to the posterior margin and outer aspect of the internal pterygoid muscle. The internal lateral ligament was attached to the Glasserian fissure and inner aspect and posterior margin of the ramus of the jaw, but not at all to the margin of the inferior dental foramen or spine of sphenoid.

Case 2. On the right side of a well-developed female subject, a thin muscular layer, rather more than $\frac{1}{2}$ inch broad, was found closely blended above (where it was tendinous) with the hinder portion of the so-called internal lateral ligament. Its lower muscular fibres arose from the inner aspect of this fascia almost as far down as the inferior dental canal. The muscular fibres ended in aponeurotic ones, partly blended with the outer surface and posterior margin of the internal pterygoid muscle and partly attached to the posterior border of the external pterygoid plate. There was no attachment of the internal lateral ligament to the spine of the sphenoid or the margin of the inferior dental foramen, but to the posterior margin and inner aspect of ramus of lower jaw and above to the inner part of the glenoid fossa and Glasserian fissure where it was well developed. The pterygo-spinous ligament was well marked.

I have been unable to find any description of the six last forms in M. Testut's *Anomalies Musculaires* (1884), or in any other of the numerous works I have consulted. Gruber has described a slip extending from the pterygoid fossa to a band extending from the spine of the sphenoid to the angle of the jaw (see *Neue Anomalien*, p. 13). In many of the above cases the band between the spine of the sphenoid and the margin of

the inferior dental foramen was entirely absent, in some only feebly marked; on the other hand, a dense band was seen, in all cases extending from the Glasserian fissure to the inner aspect or posterior margin of lower jaw.

The above series is interesting in considering the development of the various structures concerned, as well as from the fact of its tending to bear out the truth of Professor Humphry's statement regarding this so-called internal lateral ligament. The situation of the auriculo-temporal nerve, between the capsule of the temporo-maxillary articulation and the (frequent) prolongation backwards of this fascial band, would at once show the fallacy of regarding the latter as the true ligament of this articulation; this is confirmed by its true formation from the fibrous layer of Meckel's cartilage in the mandibular arch between the surfaces of the two pterygoid muscles.

THE FATE OF THE NOTOCHORD AND DEVELOPMENT
OF THE INTERVERTEBRAL DISC IN THE SHEEP,
WITH OBSERVATIONS ON THE STRUCTURE OF
THE ADULT DISC IN THESE ANIMALS. By E.
W. CARLIER, M.B., *Senior Assistant to the Professor of
Physiology in the University of Edinburgh.* (PLATE
XX.)

IN the course of my general histological work I happened to notice that the nucleus pulposus of the intervertebral disc of the adult sheep was not always situated in the centre, but had more frequently an eccentric position in the disc; I therefore resolved to investigate the subject from an embryological point of view.

E. H. Weber¹ was amongst the first to notice the gelatinous part of the intervertebral discs, and Luschka² first pointed out that this gelatinous matter is referable to the notochord. Dursy,³ on the other hand, denies that the chord participates in the formation of the nucleus pulposus, while Heiberg⁴ and Kölliker support Luschka's statement. Balfour⁵ states that in mammals the notochord becomes first constricted in the centres of the vertebræ, and disappears in these after ossification; that in the intervertebral discs it remains unconstricted, and after undergoing histological changes remains throughout life as part of the nucleus pulposus in the axis of the intervertebral ligaments. He also observed a slight swelling of the notochord near the upper and lower margins of each vertebra.

Kölliker⁶ believes that the notochord in man and higher mammals is not a cartilaginous rod, though it may be somewhat analogous. He states that the notochord remains for a considerable time in the intervertebral discs, and he describes, in new-born animals, a cavity in each disc equalling half the disc in length, occupied by a kind of soft mucous jelly coming mostly from the chord, but to some extent also from the softened elements of the disc itself, the remains of the chord being in patches, with nucleated cells full of vacuoles filled with fluid

¹ Meckel's *Archiv*, 1827.

² Luschka, "Die Altersveränderungen des Zwischenwirbelknorpel" (Virchow's *Arch.*, t. ix. p. 311, 1856).

³ Dursy, *Z. Entw. d. Kopfes d. Mensch.*, &c., Tübingen, 1869.

⁴ Heiberg, *Schenck's Mittheil.*, *Wien. Inst.*, liv. ii., 1879, p. 119.

⁵ Balfour, *Embryology*, vol. ii. p. 460.

⁶ Kölliker, *Embryology* (French edition), 1882, pp. 415-439.

surrounded by a striated tissue containing round or stellate cells, sometimes like mucous tissue, sometimes like soft cartilage in appearance. With regard to the rabbit, he says the notochord is eccentric in position, being placed nearest the back; nodes are seen on the chord corresponding to the intervertebral discs. At a somewhat later period the backward projection is more marked. The disposition of the cells of the chord is remarkable. Within the vertebræ the cells are elongated, fibre-like; in the expansions of the notochord the cells are elongated in the long axis of the discs, as if the cells of the chord had been pushed into the discs by the bodies of the vertebræ; and no doubt the rapid growth of the cartilage produces a drawing out of the cells of the chord situated in it, which would therefore accumulate in the discs. The swellings of the chord in the thoracic region are smaller than in other regions. Subsequently the cells of the chord produce cartilage. The sheep seems to differ from the rabbit mainly in exhibiting an earlier tendency to form cartilage.

THE NOTOCHORD.

I procured many sheeps' embryos, which I prepared according to methods to be afterwards detailed. I would merely state that most of the sections were made in a vertical-antero-posterior direction, and that, by using eosine and iodine-green as a double stain, I was enabled to stain fibrous tissue of a pink, and cartilage of a green colour.

I first examined the *lumbar region* only, with the following results:—In very young embryos the notochord runs in a straight line down the middle of the vertebral column, but ere long a change is observable. In an embryo $1\frac{1}{4}$ inch in length the notochord runs nearer the anterior than the posterior surface of the column, and shows a slight bending forwards in each intervertebral segment (Pl. XX. fig. 1). In an embryo $3\frac{1}{4}$ inches long this anterior position of the notochord is much more marked, while the slight bending in the disc is transformed into a well-marked V-shaped curve, with its apex pointing anteriorly (Pl. XX. fig. 5). In an embryo 5 inches long there is little change. In one 7 inches long the appearance is similar, with this exception, that the vertebræ, having now become almost completely ossified, the notochord has disappeared in them, remaining only in the intervertebral segments, where the apex of the V appears to be spreading out laterally to form a discoid flattened mass.

I next examined a foetus just after birth, in which the notochord can be seen situated anteriorly, little of it remaining,

however, except the apex of the V, the limbs having gradually been absorbed. In the adult condition the apex of the V alone remains as the nucleus pulposus.

If the *dorsal region* be now examined, a similar series of changes may be observed in the notochord, with this exception, that the chord is placed nearer the *posterior* than the anterior surface of the vertebral column, with the apices of its V-shaped bends directly *backwards* (Pl. XX. fig. 3), the nucleus pulposus in the adult being also nearer the posterior than the anterior aspect.

There is a regular transition between these two extremes of position in the mid-dorsal and mid-lumbar regions, so that if the chord be traced downwards, it is seen gradually to leave the posterior aspect, to cross the middle line, and finally in the lumbar region to reach to the anterior aspect of the vertebral column. At the junction of the dorsal with the lumbar region, one or two intervertebral segments may be observed in which no V-like bending can be seen, the notochord spreading out equally in either direction (Pl. XX. fig. 4).

In the *cervical region* the arrangement is similar to that in the lumbar region, only less marked, and the chord is more central in position. The transition between its position in the cervical to that in the dorsal region takes place in a similar manner to the transition between the dorsal and lumbar regions.

In the *sacral region* the position of the notochord is again found nearer the dorsal than the ventral aspect of the vertebræ, but the bends instead of being V-shaped are now C-shaped, with the convexity directed dorsally (Pl. XX. fig. 6). The transition from the lumbar to the sacral region is not gradual, but abrupt, the notochord crossing obliquely within one of the vertebræ.

If we consider the spinal column in its whole length, we see that in the cervical region the notochord is nearly central in position with the apices of its V-shaped bendings projecting anteriorly; that it crosses the middle line at the junction of the cervical with the dorsal region, the disc between the 7th cervical and 1st dorsal vertebra exhibiting a spreading of the notochord in all directions. That in the dorsal region the notochord lies near the posterior surface of the spinal column, with the apices of

the V-like bendings directed backwards, the bendings projecting more and more until a maximum of backward projection is reached in the mid-dorsal region, then less and less till the notochord again crosses the axial line at the junction of the dorsal with the lumbar region; one or two discs in this region showing the notochord swelling out all round. That in the lumbar region the chord lies near the anterior surface of the vertebral column, with its V-shaped bends pointing anteriorly, a maximum of anterior projection being reached in the mid-lumbar region; that the chord again crosses the axial line at the junction of the lumbar with the sacral vertebræ, the chord crossing in the first sacral vertebra obliquely from before backwards; and that in the sacral region the chord lies quite near the posterior surface of the spinal column, the bends passing from a V to a C-shape. The slight swelling of the chord near the two extremities of each vertebra, as described by Balfour, is also visible in most cases. From the foregoing it is seen that the notochord follows very closely the curves of the vertebral column, and it would appear that in the dorsal and sacral regions the portions of the vertebræ situated on the ventral aspect of the notochord grow more rapidly than those on its dorsal aspect, whilst in the lumbar and cervical regions it is the opposite.

The tissue surrounding the notochord is at first composed of a mass of undifferentiated embryonic cells, which, however, soon become irregular in shape, and produce a jelly-like matrix. Next, the cells dispose themselves in rows, arranged concentrically around a spindle-shaped mass of similar but somewhat denser tissue. This mass has one of its poles projecting into the hollow of the V-shaped bend of the notochord, and by its growth would appear to press upon and force the notochord to assume its peculiar shape (Pl. XX. figs. 3, 5, 6); while in fig. 4, where no spindle-shaped body can be seen, the chord has spread itself out into a plate in the centre of the loose connective tissue which is arranged concentrically around it. Whether this unequal growth of the vertebral column produces the bending of the notochord, or whether the bending of the notochord necessitates the unequal growth of the column I must leave undecided.

As development proceeds, the notochord disappears in all

those parts of the head and spinal column that are converted into bone; therefore in the head no trace of the notochord ever remains in the adult. It is in the intervertebral segments, and in them alone, that any remains of the notochord can be found during adult life.

The cells of the notochord, which are at first somewhat rounded, become spindle-shaped or irregularly elongated, as described by Kölliker, and as shown in the figures. They again assume a rounded form, produce cartilage capsules, and ultimately undergo degenerative changes before the end of the first year; in which degenerated condition they seem to remain throughout life. They will be further alluded to in treating of the adult disc.

DEVELOPMENT OF WHITE FIBRO-CARTILAGE AS SEEN IN THE INTERVERTEBRAL DISC OF THE SHEEP.

The loose embryonic cells which surround the notochord at first gradually produce a jelly-like matrix, resembling that of mucous tissue. Fibrils subsequently make their appearance in this matrix, and the tissue then closely resembles that form of fibrous tissue known as Wharton's jelly, in which the cells are irregular in shape, and scattered amongst the fibrils. The fibrils become more numerous and arrange themselves in lamellæ, around a spindle-shaped mass, produced in the centre of the disc. Possibly this, by its growth, bends the notochord, and with it the lamellæ on the opposite side, which therefore also became V-shaped (Pl. XX. figs. 3, 5). Gradually, as age advances, this spindle-shaped mass opens out, becoming looser in texture, and ultimately indistinguishable from the rest of the disc. This fibrous tissue undergoes a change with advancing age, whereby its chemical nature is altered. The cells begin to secrete hyaline capsules around them of a cartilaginous nature, and the fibres and matrix of the connective tissue gradually become infiltrated with chondrogen: consequently they are no longer stained pink, but purplish and then green, in the eosin-iodine green stain. This change can be seen occurring in embryos of the length of 7 inches; it is more marked at birth, and is complete before the end of one year.

From the foregoing it will be seen that the centre of the disc is not entirely composed of altered notochord, as has been described, but of an altered fibrous tissue. The peripheral parts of the disc are from the first composed of fibrous tissue, staining red in eosine (Pl. XX. fig. 1). It is arranged in lamellæ which are continuous with the periosteum of the vertebræ, and which are in all cases more numerous on the anterior than on the posterior aspect of the discs (Pl. XX. figs. 2, 3, 4, 5, 6). The peripheral lamellæ retain this character throughout life, being composed of a true fibrous tissue, as described by Klein, and not of cartilage as many have stated. The greater abundance of true fibrous tissue on the ventral aspect of the whole vertebral column, binding the vertebræ firmly together on that aspect, is doubtless of service in resisting the strain due to the weight and movements of the body.

THE ADULT DISC.

In the adult disc two structural elements may be considered—the fibrous and cellular.

The fibrous element, of which the greater part of the disc is composed, is arranged in lamellæ, many of which encircle the whole disc; some, however, exist only on the anterior, become thinner at the sides, and never reach the posterior aspect (fig. 8, 2, 4, 5). The lamellæ show a concentric arrangement around a mass of tissue, the remnant of the notochord. The lamellæ vary in thickness, those near the surface are the thinnest, but many thin lamellæ may be found scattered among those that are thicker and more centrally placed. The lamellæ vary in direction; the outer lamellæ are arranged concentrically (fig. 8, 1); immediately internal to these are lamellæ which are also concentric but which bulge out posteriorly, and so resemble the shape of an elbow-piece of ancient armour (fig. 8, 3). Within these are other lamellæ, the central parts of which bulge outwards all round the disc, and have therefore the shape of two truncated hollow cones united by their bases (fig. 8, 6); while within these again are lamellæ which in vertical section are seen to enclose an ovoid mass containing the remains of the old notochord. These, unlike the other lamellæ, never reach the adjacent surfaces of the vertebræ between which the disc is placed (fig. 8, 7). All the other

lamellæ are firmly attached to the bone. Within the elliptically-arranged lamellæ there is a felted fibrous mass, the fibres of which run in all directions.

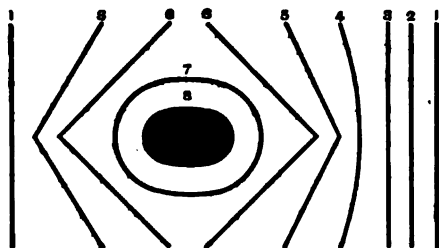


FIG. 8.—Schematic representation of the arrangement of the fibrous lamellæ in an intervertebral disc, from the dorsal region of an adult sheep. 1, concentric lamellæ; 2, 4, 5, lamellæ incomplete on the posterior aspect of the disc; 3, lamella of the shape of an elbow-piece of ancient armour; 6, lamella of the shape of a double truncated cone; 7, ovoid lamella; 8, centrum of felted fibres containing the remains of the notochord.

Arrangement of Fibres in the Lamellæ.—In the outer lamellæ the bundles of fibres are arranged obliquely, in such a manner that the fibres of two neighbouring lamellæ cross each other at a wide angle. In the lamellæ, which are disposed like an elbow-piece, the same arrangement occurs anteriorly, but the fibres gradually become less and less inclined, until in the middle line posteriorly, they are parallel and run vertically. In the lamellæ arranged like truncated cones, the fibrous bundles cross one another anteriorly at a more acute angle, whilst posteriorly they resemble those of the last-mentioned lamellæ. In the ovoid lamellæ the fibres are arranged in a manner closely resembling the lines of longitude on a globe. In the central mass the fibres run in all directions, thus giving a tangled or felted appearance to it.

From a mechanical point of view the arrangement above described forms a firm yet elastic whole—most rigid at its periphery where the lamellæ are most vertically placed, more elastic towards the centre where the lamellæ are placed like carriage springs, breaking any shocks which the vertebral column may sustain in the direction of its length. Yet the external lamellæ are not devoid of elasticity, as the oblique decussating arrangement of the fibres will allow of a certain amount of compression of these lamellæ in a vertical direction.

Such an arrangement must be highly beneficial to animals such as the sheep, that fight by butting with the head.

The fibres of the different lamellæ exhibit a remarkable difference in their staining properties, which points to a difference of chemical composition. Those of the lamellæ nearest the periphery of the disc stain of a deep pink with eosine and picrocarmine, swell up and become transparent when treated with acetic acid, and become converted into gelatine on prolonged boiling. They are, therefore, of the nature of white fibrous tissue. The fibres of lamellæ, situated internal to these, acquire a purplish tint on double staining with eosine and iodine-green, swell up imperfectly in acetic acid, and are only partially converted into gelatine on boiling, the jelly forming in little patches, whilst the remaining tissue swells and becomes white and opaque like cartilage. They therefore partake of the nature both of white fibrous tissue and of cartilages. The fibres of lamellæ still more centrally placed (Nos. 5, 6, 7, &c., in fig. 8) acquire a green instead of a purple colour on double staining with eosine and iodine-green; they are unaffected by acetic acid, and become swollen, white, and opaque on boiling. They have, therefore, the composition of cartilage, and yield no gelatine. It is peculiar, to say the least, that in the green parts it is not the hyaline interstitial substance of the matrix that stains so vividly, as one would be led to expect from the behaviour of hyaline cartilage stained in a similar manner, but the fibres imbedded in it. Since these fibres, as already stated, stain red in the young embryo, they must have become infiltrated with chondrogen.

The Cellular Element.—In the outer lamellæ the cells are reduced to thin plates; their nuclei alone being visible, they resemble in appearance the cells of adult tendon as seen in transverse section; if, however, lamellæ be torn from a fresh disc, teased in acetic acid, and stained in magenta, the cells may be seen in rows between the bundles of fibres, and clasping them; they closely resemble the cells which are found in the tendons of the tails of young rats when treated in a similar manner. They are, however, more irregular in shape, and here and there one may find a thin cartilage capsule enclosing a cell.

In all the inner lamellæ the cells closely resemble those of cartilage, each cell being surrounded by a hyaline capsule. Many are rounded in shape, but most cells are branched. The cells are arranged in rows, as one would expect from their arrangement in the foetal condition. In profile view, the cells often appear spindle-shaped, some showing very long processes which occasionally anastomose with processes of neighbouring cells. In surface view, the cells present a more or less oval outline, with several branches. The cartilage capsule enclosing each cell is prolonged around the processes. Sometimes two cells are enclosed in a single capsule, each cell being surrounded by a thin daughter capsule of its own, as in hyaline cartilage.

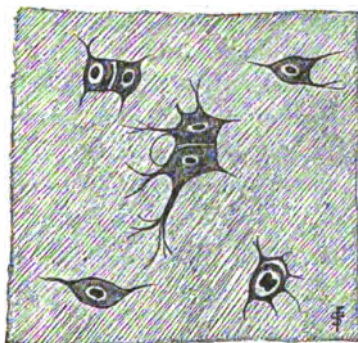


FIG. 9.—Branched cells of white fibro-cartilage from the region corresponding to 6, fig. 8.

The cells in the loose tissue, between the lamellæ, often have a striking appearance. They are scattered irregularly, and on surface view show numerous very long and much branched processes. They are also surrounded by cartilage capsules extending to the very tips of the processes (fig. 9). Some cells also exhibit signs of recent division, and are best seen near the upper and lower surfaces of the disc, where the lamellæ are wider apart than in its centre.

Remains of the Notochord.—I have already alluded to an ovoid mass, somewhat centrally placed in the disc, and have spoken of it as a tangled mass of fibres, but when examined more closely, it is seen to consist of cells embedded in a matrix

of hyaline cartilage surrounded by a tangle of fibres. These cells are all that remain of the notochord, and occupy the position of the apex of the V-like bend of the notochord seen in the embryo. The cells in these groups often have a degenerated appearance, many small cells being situated in one enlarged cell-space, similar to those that occur so frequently in the calcified costal cartilages of old persons. Some of these small cells may exhibit a thin capsule, but many of them are quite devoid of such a capsule, and resemble broken-down nucleated particles of protoplasm. This appearance of the *nucleus pulposus* has long been known; but besides these masses there are other cells of the notochord which seem to have escaped notice hitherto.

Towards the centre of the disc some cells may be seen that appear to have penetrated into the lamellæ, broken them up somewhat, and altered their nature, causing a fogged or misty appearance of their fibres. The cells themselves resemble those of cartilage, and are often of large size, surrounded by cartilage capsules. How the misty material is produced I am quite unable to say. These cells appear to be derived from a few cells of the notochord, which do not participate in its general bending, but seem to remain behind in the centre of the disc; these cells will be seen in the embryonic condition on referring to Pl. XX. fig. 1, m.

Attachments of the Intervertebral Disc to the Vertebrae.—At the margins of the disc the bundles of fibres of the lamellæ are continuous with the fibres of the periosteum of the vertebrae. Further in a line of demarcation is visible between the epiphysis and the disc; this line is evidently a sectional view of a plate of tissue, which separates the disc proper from the bone. The line is irregular, and stains of a violet or dark green colour; the irregularities which it presents are due to little elevations or depressions in the plate, caused by the presence in these localities of blood-vessels or little groups of cells, which indent its surface (Pl. XX. fig. 7). There are two of these plates, in one at the upper and one at the lower surface.

The fibres of the lamellæ which abut against these plates may be traced through them into the bone matrix, where they fade away, and by this means a very firm attachment of the discs to the vertebrae is secured.

My best thanks are due to Mr S. Fowler who has kindly made the drawings for me from microscopical preparations.

METHODS.

All the embryos which I obtained were fixed with Kleinenberg's picro-nitric acid solution, the process being subsequently completed with alcohol. The sections were all cut in gum with a freezing microtome. Adult tissues were placed in a bone-softening fluid compound of 52 grammes of chromic acid dissolved in 1000 c.c. water, to which 10 c.c. commercial nitric acid is subsequently added. This fluid was changed every second day till the bone was sufficiently soft, after which the tissues were well washed in water and preserved in spirit.

The following method of staining appears to me to yield the best results, especially when dealing with adult tissues. Sections prepared as above are placed in methylated spirit for two or more days, after which they are placed in water to wash out the spirit, and transferred to water solution of eosine (1:1200) for one hour, then washed in distilled water to remove the superfluous stain, and placed in aqueous solution of iodine green (1:1200) for an hour, then washed in distilled water for a few minutes, and mounted in balsam by the usual method. The stain is permanent in balsam. For embryonic tissues half an hour in each dye is sufficient, but the preparations soon fade. In this way an excellent double stain is produced, the fibrous tissue becoming a brilliant pink, whilst cartilage is stained green; where fibrous tissue and cartilage intermingle the general tint is purplish.

When stained thus the individual fibres of the central portions of the disc stand out remarkably, each being quite distinct from the matrix in which it is imbedded. For cells this method is not very satisfactory, since they tend to shrivel, but with care this may be avoided. The cells stain red, their nuclei green. For the cell capsules this stain is invaluable, the finest processes being stained green, and standing out sharply from the surrounding matrix. For the cells an aqueous solution of hæmatoxylin is perhaps best, and should be used with glycerine as a mounting fluid. Unfortunately the colour fades after a time.

EXPLANATION OF PLATE XX.

- d.* Dorsal aspect of vertebral column.
- v.* Ventral aspect of vertebral column.
- b.* Cartilaginous vertebra.
- c.* That part of the intervertebral disc that becomes converted into white fibro-cartilage.
- f.* That part of the intervertebral disc that remains throughout life as white fibrous tissue.
- n.* Notochord.
- s.* Spindle-shaped body.
- p.* Perichondrium.
- m.* Cells of notochord which do not participate in the general bending.

Figs. 1 to 6 are vertical antero-posterior sections of the vertebral column of embryo sheep.

Fig. 1. Embryo sheep, $1\frac{1}{2}$ inch long. Mid-lumbar region, showing a slight bending of the notochord towards the ventral aspect. $\times 300$.

Fig. 2. Embryo sheep, 3 inches long, cervical region, showing the V-shaped bend of the notochord directed towards the ventral aspect. $\times 100$.

Fig. 3. Embryo sheep, 5 inches long. Mid-dorsal region, showing the V-shaped bend of the notochord directed towards the dorsal aspect. $\times 50$.

Fig. 4. Embryo sheep, 5 inches long. Junction of dorsal and lumbar regions, showing the notochord spread out equally in all directions. $\times 50$.

Fig. 5. Embryo sheep, $3\frac{1}{4}$ inches long. Mid-lumbar region, showing the V-shaped bend of the notochord directed towards the ventral aspect. $\times 100$.

Fig. 6. Embryo sheep, 9 inches long. Sacral region, showing the notochord directed dorsally, the V-like bend being replaced by an arc-like curve.

Fig. 7. Junction line between disc and vertebra. *b*, bone of vertebra; *c*, hyaline cartilage; *j*, junction line; *f* white fibro-cartilage of disc.

DISPOSITION OF THE VERTEBRAL COLUMN IN
HANGING (AND SWINGING) POSTURES. By
JAMES CAGNEY, M.A., M.D., *Demonstrator of Anatomy,
St Mary's, Physician to Out-Patients' Hospital for
Epilepsy and Paralysis, Regent's Park.*

(Read before the Anatomical Society of Great Britain, February 26, 1890.)

It has been assumed, so far as I know without any evidence, that the vertebral column may be stretched by suspension of the body, and that what is true of the whole is true of each of its parts. The question is one of general interest and of much practical importance at the present time, and I propose to test the truth of the assumption in the case of each of the curves separately. This may be done, partly by direct observation, partly by legitimate inference, based on anatomical facts.

Professor Humphry¹ has shown that the three curves—cervical, thoracic, and lumbar—which form the supra-pelvic portion of the column are approximately the arcs of circles, and that their cords lie in one vertical line, which is the line of gravity of the head. This applies to the erect posture; but it is no doubt also true when the body hangs freely, and in my view it is then a defensive factor of great importance. Again, according to the same eminent authority, the thoracic curve backwards is about equal to the cervical and lumbar curves forwards taken together. The thoracic curve is, therefore, from its extent, the most important, while the movements of which it allows are the fewest and least complicated; hence it will first engage attention. It differs from the others in direction, and in the fact that the spinal cord lies not in its concavity but on its convexity.

The straightening of this curve by traction at its two ends will be attended with lengthening of its concave anterior line and shortening of its posterior convex line. Both these changes may be estimated by direct measurement on the cadaver. I have made a series of such observations,² and I have found that

¹ *The Human Skeleton*, p. 143.

² The observations referred to are given in detail in the writer's paper on "The Mechanism of Suspension," *Trans. Roy. Med. and Chir. Soc.*, 1890.

there is invariable *lengthening* measured along the bodies of the vertebræ anteriorly from the 1st dorsal to the 1st lumbar. This ranges between $\frac{1}{2}$ to $\frac{7}{8}$ inch, and averages $\frac{1}{2}$ inch. At the same time, a tape applied to the summits of the dorsal spines from the 1st to the 12th shows that there is a *shortening* on that surface of about $\frac{1}{2}$ inch. This last measurement can be made on the living as well as on the dead body, and it is always greater in the former, the difference being an effect of muscular tension, which will be again referred to. From these facts, it appears that the hinder surface of the column contracts while the bodies open out anteriorly, and that therefore there is a point of rotation round a transverse horizontal axis between each pair of contiguous vertebræ. This point of rotation must be at the posterior edges of the upper and lower surfaces of the bodies of the vertebræ. It is well known that the bodies of the dorsal vertebræ are thicker behind than in front, whilst the intervertebral discs are of the same thickness throughout. In an expansion or straightening of the curve the points where the bones are thickest will be approximated, and the intervertebral substance will undergo the utmost compression there; and thus a series of fulcra is provided in a line just in front of the spinal canal. The segments behind the fulcra approach each other, and therefore the spinal canal is shortened; but shortening of the spinal canal in any part implies a relaxation of that portion of the spinal cord which is within it.

I desire further to show that a shortening and a relaxation take place in all three curves when the body hangs freely, and that they are effected in each in a different manner. The defensive function of the vertebral column lies largely in the provision which it makes for this shortening, and the peculiarities of the vertebræ contribute to it. Some notice of these is therefore called for.

Attention has already been directed to the greater thickness of the posterior surface as compared with the anterior surfaces of the bodies of the vertebræ in the dorsal region, and to the important movements determined by it. The same fact causes extreme tension of the anterior common ligament, and, by preventing any gliding of the opposed surfaces upon one another, promotes a resolution of forces notably different from that which

will be found to take place in the neck. At the same time, the weight of the body is thus causing a tension of the ligament in front and a compression of the intervertebral substances behind. Secondly, the overlapping of the spines and laminæ in the dorsal region favours the involution of the neural arches. Thirdly, the intervertebral foramina being placed entirely behind the bodies—that is, behind the axes of rotation—share in the contraction of surface. They are elongated ovals, with their long axes directed upwards and backwards, and the nerves are protected entirely by the vertebra above. Thus, when the curve straightens out, the nerves are still sheltered, and the foramina approach to the shape of circles. In the dorsal region they are situated more posteriorly, with reference to their respective bodies, than either in the neck or loins. This peculiarity is ascribed by Professor Humphry to the direction which the nerves have to take in order to reach their respective destinations; but it appears there is another object attained by it. The dura mater is reflected on the nerve-roots, and attached by strong processes to each pair of intervertebral foramina. It thus forms a series of ligaments enclosing the nerve-roots, which relax as the cord relaxes in order to maintain the relative position of the roots, and to secure that they shall be nowhere stretched. Thus the place of attachment in the dorsal region is well behind the point of rotation, being relatively most posterior at the summit of the curve, and inclining gradually forwards toward the lumbar and cervical regions. It follows also from this that, as the spine straightens out, the points of emergence of the nerves from either side of it approach to a vertical plane.

Since the lumbar and cervical curves have a different direction from the thoracic, they are affected by suspension in a different manner, and since they support the spinal cord in their concavities, the provisions for its defence will be of another kind. The ultimate object, however, is the same, namely, the relaxation of the cord in the position of rest.

When the body is hung up either from the head or from the heels, and the distance along the lumbar spines measured before and during suspension, no change will be found. This is due to the great strength of the ligaments upon which the weight

is directly thrown. If the eviscerated cadaver be hung up by the head, and the distance along the front of the bodies of the lumbar vertebræ be taken before and during suspension, it will be found that it is less in the latter condition by about $\frac{1}{2}$ an inch. The lumbar curve is caused chiefly by the greater thickness of the intervertebral discs anteriorly. The tendency to straighten this curve, and to bring the centre of gravity of the body within the line of support, is resisted behind by strong ligaments, and therefore acts in front by compression of the intervertebral discs. The vertebræ close upon one another like hinges, the points of rotation being at the spines. The spinal canal, which is in front of these, becomes approximately a straight line, or the segment of a greater arc, and is therefore shortened.

When the body is hung up *by the heels*, the cervical curve adapts itself in a similar manner, but by a different mechanism. The posterior ligaments are many and strong, and adequate to the weight of the head. There is therefore no stretching of the concavity. The effort to bring the line of support over the centre of gravity below effects another disposition. The anterior common ligament is relaxed, and a gliding movement of the vertebræ is permitted. This is promoted by the great quantity of semifluid intervertebral substance which exists in this region, and it is directed by the lip-like projection on the lower (now upper) border of the bodies in front. I am disposed to see in the necessary movement in question the developmental cause of this remarkable peculiarity in the shape of the cervical vertebræ. The upper anterior edges (undermost in this position) glide backwards on the retreating surface of the disc, and each vertebra rotates round a transverse axis through its body. The spinal canal is encroached upon by the projection into it of that edge of the posterior surface of the body which is nearest to the head, the greater roominess of the cervical canal in this region than elsewhere rendering the intrusion possible. At the same time the intervertebral discs are compressed in front, and in this way the curve tends to straighten. As the curve straightens out the spinal canal straightens also, and since its extreme points are not separated, it shortens. The rotation of the vertebræ also has, *pro tanto*, the effect of further shortening the canal and relaxing the cord.

If, instead of hanging by the hind limbs, a body be suspended from the head, the same forces come into play, but they are less equal to the strain. The curve is first reduced in front.¹ There is reason to believe that the 3rd vertebra is made the fixed point. An incision through the anterior common ligament between this and the 4th did not gape. At the same time the ligaments behind are overstretched. The position is undoubtedly one of danger to heavy animals, because the necessary and inevitable movement is in the direction of dislocation. The cord cannot be stretched without tearing the dura mater, but the safeguard of relaxation is to some extent obviated. Comparative measurements of the entire neck are uncertain and unsatisfactory, from the difficulty of giving the head the proper position in the preliminary estimate. When taken below the 2nd vertebra they show an elongation on both surfaces, which is greater behind than in front.

From the foregoing observations, it would appear that when the body hangs freely in the position contemplated by nature, *i.e.*, by the arms or legs, the vertebral column which has for its function the protection of the spinal cord contracts throughout, and in an equally remarkable manner in its different parts. It has been mentioned that in the erect posture the vertebral curves are so arranged, that the cords of the arcs which they describe lie in one vertical line, and it may be assumed that this arrangement obtains in hanging postures also, since the results of direct measurement, so far as it can be applied, and the anatomical inferences made here, confirm the belief that the relation between the cords remains the same, while the arcs which they subtend—in other words, the vertebral curves—alter their dimensions.

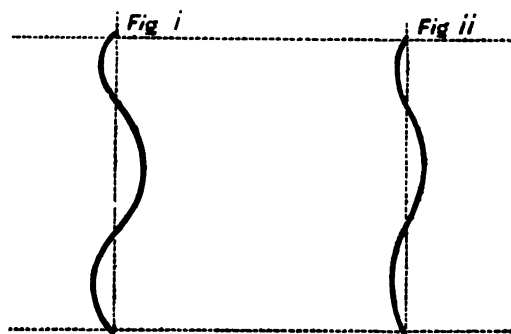
In each case, as we have seen, the curve expands, *i.e.*, it becomes the arc of a greater circle. At the same time the length of the subtending cords is invariable, since the extreme points of the curve are not separated. But the arc of a greater circle, having the same cord as a lesser one, describes a shorter line than the latter; and, in the case where the three cords are in one vertical line, such an expansion of the three consecutive curves causes the curves themselves to approximate to that

¹ Humphry, *The Human Skeleton*, p. 161.

vertical line, which is the shortest possible between the extreme points. This is illustrated by the following diagram.

The sinuous line in fig. 1 is shorter than that in fig. 2. The sinuous line represents the curves which are occupied by the spinal canal, and, as the parts of the latter approach the vertical line in which lie the cords of the arcs, the canal is shortened. This I believe to be the process in suspension.

Hitherto the effect of muscular tension has been overlooked. It will now be briefly noticed.



When a man hangs by his arms, the neck is free to assume a position of ease, but the remainder of the vertebral column undergoes a change of shape. To hang from the arms is practically to hang from the scapulae and clavicles, and ultimately from the points where the muscles connected with those bones are attached to the trunk. Omitting the latissimus dorsi, which is of a mixed character, these muscles may be divided into two classes—(1) those (rhomboids and trapezius) which arise from spinous processes; (2) those (pectorals, serratus magnus) which are attached to ribs. The first of these will approximate the dorsal spines and increase the dorsal curve in the same manner as gravity moving the vertebrae upon the axes of rotation, which we have seen to exist in the dorsal region.

The action of muscles of the second class is similar. They are attached to the ribs externally to their heads. Each rib thus becomes a lever of the second order, and, when raised, carries with it the transverse process to which it is firmly attached by the costo-transverse ligaments. The transverse

processes spring from behind the bodies in the dorsal region, and therefore these muscles co-operate with those of class 1 in approximating the neural arches by rotating them upon the transverse axes at the posterior edges of the bodies.

In the lumbar region the psoas, and in the cervical region the prevertebral muscles, are placed on that aspect of the spine where their action would aid in causing a relaxation of the spinal cord. The front of the thoracic curve is the only situation where the action of muscles would oppose the fundamental process, and there no muscles exist.

NOTE TO DR HOORWEG'S PAPER "PHYSICAL
NOTES ON THE MOTION OF THE BLOOD IN
THE HUMAN ARTERIES."

OWING to the delay in obtaining from Germany some of the wood blocks in illustration of Dr Hoorweg's paper in the April number of the *Journal*, we were compelled to go to press before one of these cuts, in illustration of the exact form of the pulse-curve, had reached us. The description of this cut is on p. 454, section 12. The cut has since been forwarded, and we now append it in illustration of the description. It applies to the paragraph beginning "The lever's point," &c.

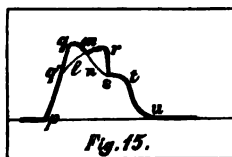


Fig. 14a.

In cutting figures 12 and 13 the engraver had omitted to insert the signs of the electric sparks, an omission which we now supply. These figures are to be substituted for figures 12 and 13 inserted on pages 452 and 453.



Fig. 12.



Fig. 13.

THE PATHOLOGY OF GENU VALGUM, OR KNOCK-KNEE.

By Professor HUMPHRY, F.R.S.

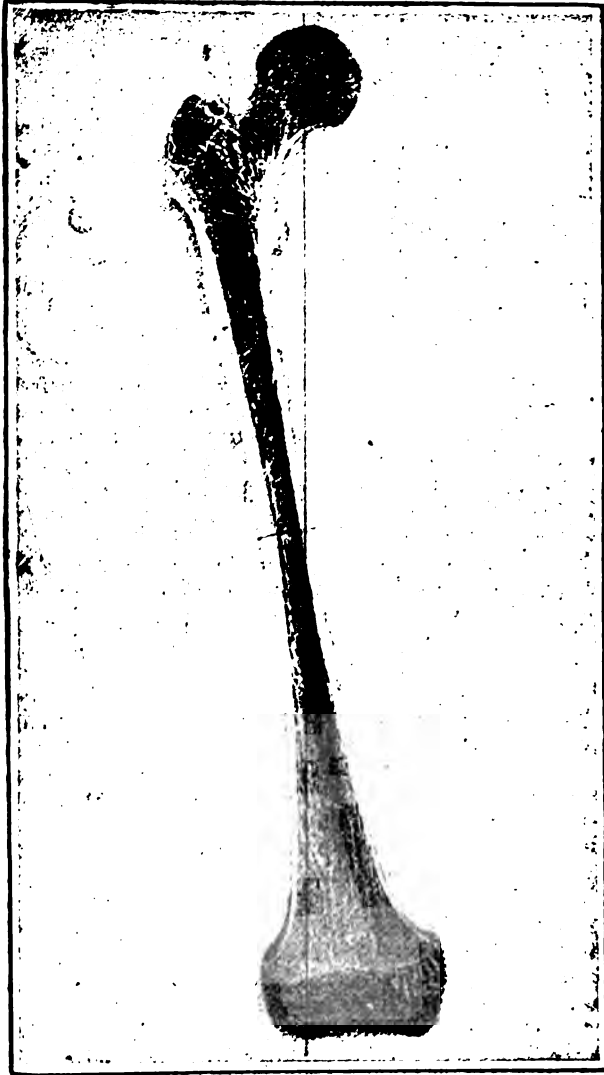
MR KEETLEY's paper on "Genu Valgum," in the number of the *Illustrated Medical News* for December 7, suggests to me to make a few remarks on the pathology of the affection.

I have for many years taught¹ that the *essential* feature of genu valgum is a *deficiency in growth at the outer part of the lower epiphysial line of the femur*. If a thigh-bone be placed (as in the photograph, which represents a section of a well-formed thigh-bone) with its lower articular surface upon a table or any horizontal plane, in the position which it normally occupies in the erect posture, a plumb-line will fall from the upper weight-receiving part of the head of the bone, obliquely, through the shaft and through the *outer* condyle (not between the condyles). This therefore is the line of weight, and the weight is borne chiefly upon the *inner* part of the shaft above, and below upon the *outer* part of the shaft, the *outer* part of the epiphysial line, and the *outer* condyle. To enable it to fulfil its greater weight-bearing function, the outer condyle, as compared with the inner condyle, is broader and flatter beneath; and a section (see photograph of the lower part of the same thigh-bone) shows it to be composed of denser cancellous plates, which have a more vertical disposition.

Further, owing to the inclination inwards of the thigh as it descends (which, by the way, is a human feature associated with the width of the pelvis and the erect posture), the muscular traction, viz., that of the *quadriceps extensor*, through the patella, that of the abductors *glutæus maximus* and *tensor vaginæ femoris*, through the ilio-tibial band, and that of the *biceps flexor*, which enjoys the advantage of leverage afforded by the projecting head of the fibula, is in all positions exerted chiefly upon the outer condyle. This conformation and relation of parts, added to the great leverage given by the thigh above and by the leg below, make a demand—rather throw a difficulty—upon the growing force in the outer part of the epiphysial line, which in some young, perhaps rickety, persons it is not quite equal to meet and overcome. It has to be observed that the growth at this epiphysial line is greater and more prolonged than at any other part of the frame. The growth also takes place almost entirely on the shaft side of the line, the addition to the epiphysis from it being slight. The defect, therefore, to which, in the main, I attribute the deformity of knock-knee, is an imperfection in the growth of the *outer* and lower part—the supra-condyloid part—of the shaft of the femur;

¹ See my lectures in the *Provincial Medical and Surgical Journal*, 1850, p. 91, my treatise on the "Human Skeleton," 1858, p. 476, and more recently a paper on "Back-knee," "Knock-knee," and some other deformities, read before the Medico-Chirurgical Society, and printed in the last volume of the Transactions of that Society.

and the imperfection is to be attributed to the insufficiency of the growing force in this part of the epiphysial line to overcome the resistance offered by the weight of the body and the traction of the muscles.



When the knee affected with this deformity is bent, two things are observed: *First*, that the leg loses its outward slant and assumes its proper direction, viz., in the same plane with the thigh. This is

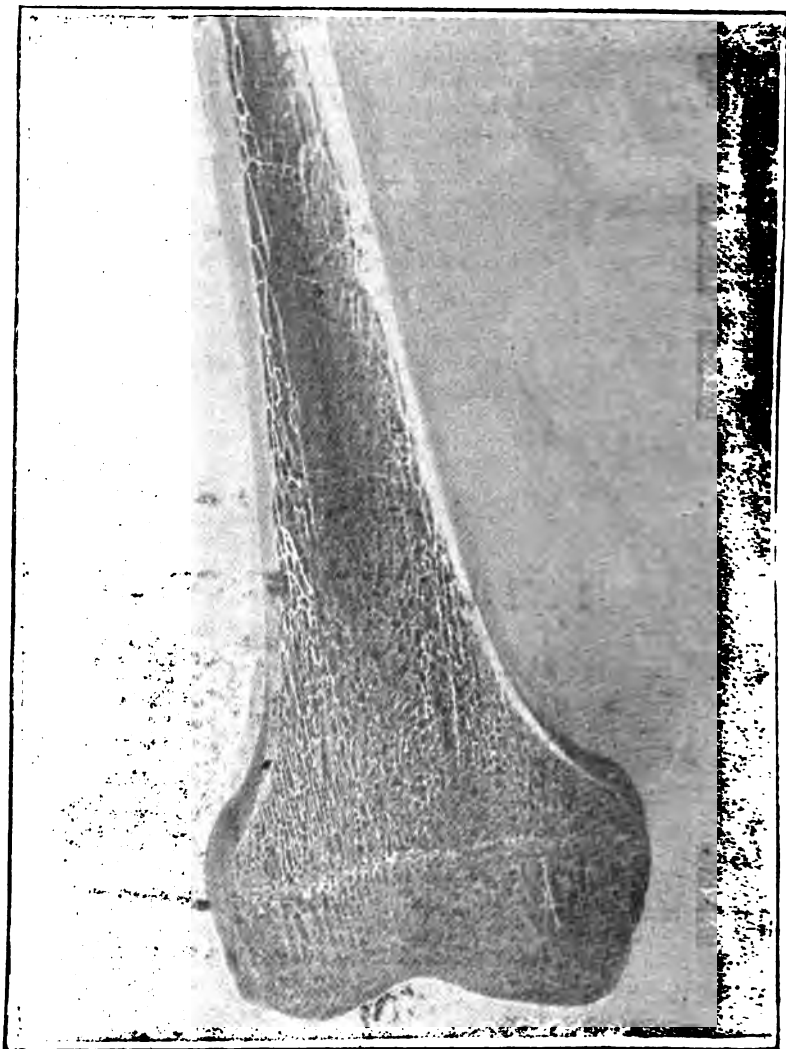
owing to the fact that the circumference of the condyle acquires its normal dimensions, inasmuch as the growth here is not interfered with by any undue pressure, and the hinder, rounder part accordingly projects backwards to the same level as does the corresponding part of the inner condyle. *Secondly*, that the patella has not its usual prominence anteriorly, which is in consequence of the absence of that prominence of the lower part of the outer condyle whereby the patella in the naturally formed knee is carried forward so as to constitute the foremost and most conspicuous feature of the flexed joint.

In the examination of specimens in many museums at home and abroad, by which the above views were confirmed, as they were still further confirmed by the observations of Mikulicz, I have seldom had reason to think there has been any undue amount of growth of the inner condyle or of the part above it; and such hyper-growth, especially unsymmetrical, in an epiphysis or part of an epiphysis, is very rare. I may add that it is difficult to see how the deformity could be produced by a relaxation of ligaments, or by any other cause than an obliquity of one or both of the articular surfaces of the bones of the joint.

Although I thus believe that the essential feature in the pathology of knock-knee is an obliquity of the under part of the articular surface of the femur, consequent on impaired growth of the lower and outer, or supra-condyloid, and chief weight-bearing part of the shaft of the femur, I am well aware that other causes may combine with this one or may exist without it. Such are (1) a similar interference with growth at the outer part of the epiphysial line of the tibia, inducing an obliquity of the articular surface of that bone. This is usually less marked than the corresponding defect in the femur, owing probably, in part, to the less amount of growth which takes place at the upper end of the tibia, as compared with that at the lower end of the femur. (2) The incurving of the lower part of the shaft of the femur, or of the upper part of the shaft of the tibia, or of both, after the manner commonly seen in the shafts of rickety bones.

A deficiency in cell-formation and a deficiency and irregularity in bone-formation at epiphysial lines are common features of rickets, and cause the deficiency of growth, especially in the lower limbs, of rickety persons. Though the cell-formative processes are deficient, the bone-formative processes are still more so. This causes that relative superabundance of unossified cells which led to the mistaken idea of an actual superabundance of them; and this causes also that bulging of the circumference of the epiphysial cartilages which is commonly observed in rickety children at the lower end of the radius, at the sternal ends of the ribs, and, to a less extent, at the bones of the knee and ankle. It is this deficiency in the power of cell-formation and ossification manifesting itself in the lower and outer weight-bearing part of the femur, and in a less degree and less often in the subjacent part of the tibia, which is the common cause of knock-knee, though, as I have said, other rickety manifestations in either or both

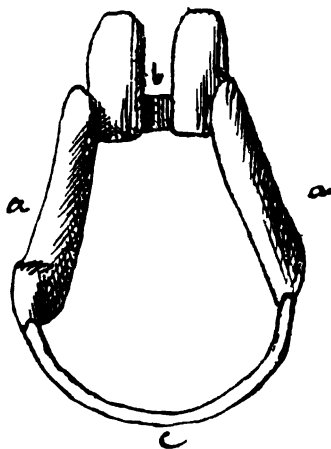
of these bones may lead to, or contribute to, the same result; and bulging at the weak and yielding parts of these epiphysial lines may not uncommonly be detected.



I may observe that in the ordinary LATERAL CURVATURE of the spine it is a similar deficiency of growth and ossification, together with bulging, at the upper and lower epiphysial lines of the centra, or bodies, of the vertebræ on one side, together with a flexure or yielding of the bodies themselves, which is the prime feature of the

deformity, and which is brought about by the weight being allowed to fall unduly upon that side; lateral curvature and knock-knee being therefore alike of a rickety nature, though both not infrequently occur after the period of life at which rickets usually manifests itself in other bones. The rickety spine of the infant is usually manifested in a bending backwards of the column at the lumbar and lower dorsal parts, and indicates a difficulty in evolving that specially human feature of the column, the anterior dorsi-lumbar curve.

With regard to treatment, I would only remark—*First*, as a preventive, that children should not be encouraged or allowed to stand and walk early, especially when the head is large. *Secondly*, the natural growing forces will commonly rectify slight abnormalities in the young. In bad cases, which are met with almost exclusively among the poor, where proper attention, &c., cannot be given, I have long used the simple frame sketched, consisting of two light wooden splints (*a a*), united below by a thin band of metal with foot-pieces (*b*), and united above by a narrow semicircular bar of metal (*c*). In this frame the child is seated, with the feet on the foot-pieces and the



buttocks within the semicircular bar, the whole being well padded; and the limbs are bandaged to the side splints so as to prevent walking, and therefore prevent any weight being thrown upon the limbs, and so as to exercise pressure upon certain parts of the limbs as may be required—upon the inner side of the knees, for instance, in knock-knee. The limbs and the child may be released at night, and the frame reapplied in the day, or it may be kept on night and day. I have found this very effective in remedying the rickety deformities of the lower limbs in children. *Thirdly*, in more severe cases, and in older children, osteotomy is required.

SENILE HYPERTROPHY AND SENILE ATROPHY OF THE
SKULL. By Professor HUMPHRY, F.R.S.

*(Abstract of a Paper read on Tuesday, May 27, 1890, at the Royal
Medical and Chirurgical Society of London.)*

ATTENTION is directed to two changes of opposite nature, not uncommon in the skulls of elderly persons, both of which are peculiar to this part of the skeleton, and both of which are rather difficult of explanation. One consists of an increase of thickness and an increase of density, and, therefore, an increase of weight, which seem to be attributable to a shrinking of the brain with consequent lessening of pressure and increase of congestion of the vessels of the skull which are supplied from the interior; this congestion leading to bone-deposition on the inside and condensation of the diploë, and affording a remarkable contrast to the rarefaction and lightening of the bones in other parts of the same subjects.

The other change consists in atrophy from without, contrasting with the atrophy in other bones which proceeds in the main from within. The skull becomes smaller and lighter, the outer table of the vault approaching the inner, and the skull-wall being consequently reduced in thickness. This change may take place uniformly, or it may proceed in some parts more than in others. The most common parts for the extreme thinning are the parietal bones on the sides of the sagittal suture, midway between it and the tubera, causing the remarkable symmetrical depressions of which many specimens exist. The case is given of a woman, aged ninety, in whom death was caused by fractures, from a fall, taking place through these depressions. Instances are mentioned in which the two changes, the thickening from within and the condensation, on the one hand, and the thinning from without with the parietal depressions, on the other, are coincident. In default of other good cause for the formation of the parietal depressions, the effect of the pressure of the occipito-frontalis tendon is suggested for consideration.

AN EASY METHOD OF DISSECTING THE EYEBALL. By
HORACE DUNCAN, B.A. Cantab., M.B. Lond., *Superintendent of
Dissections to the Conjoint Examining Board.*

SOME slight experience in preparing pupils for examination in anatomy and physiology has led me to believe that the majority of medical students very rarely dissect an eyeball.

Their knowledge, such as it is, of that important organ seems to be generally derived from diagrams and written descriptions. Why this should be so is, I think, due to the fact that the student fears the task requires some special skill in dissection beyond what he has acquired in the somewhat rough methods of the dissecting-room; especially as the text-books advise the dissection to be carried out under water, a mode which seems to be very distasteful to those who have not worked at comparative anatomy.

It is with the hope of remedying this state of affairs that I venture to publish the following account of a method of dissection which I believe to possess the merit of not requiring any special manual dexterity for its accomplishment.

The instruments required are (1) a pair of scissors (preferably a small pair with fine points), (2) a pair of forceps, (3) a scalpel, and (4) an aneurysm needle, an instrument which might with advantage be made to replace some of the superfluous scalpels at present found in dissecting cases.

Before attempting to dissect the human eye, the student had better first practise on the eyes of sheep. The first thing to be done is to clear the globe of all muscles, fat, &c. Having done this, the dissector is to hold it in his left hand with a finger pressing against the cornea and the thumb against the opposite pole, so as to make the "equator" tense. Holding the scissors in his right hand, so that the blades are on the flat against the equator, let him now by a rapid motion snip off a small piece of the sclerotic.¹

One blade of the scissors is next to be introduced (through the window) between the sclerotic and choroid, and the sclerotic is to be divided round the equator until within a short distance of the window. This may be done without fear of wounding the subjacent choroid, if care be taken to keep the point of the lower blade projecting upwards, *i.e.*, against the sclerotic. Having made this circular cut, place the eye on the table by resting it on its posterior pole, and by means of the forceps turn up as much as possible of the anterior flap just as one turns up the collar of a coat. This can be done as far as the "white ring." The flap must then be held on the stretch, and the white ring broken through by gently pushing

¹ I have chosen the equator as the region for making this window, because the sclerotic is thinner there than elsewhere.

the handle of a scalpel against the sclerotic. After doing this, by pushing the handle a little further on, the ligamentum pectinatum iridis (the reflection of the posterior lamina of the cornea on to the front of the iris at its periphery) will be divided, and immediately afterwards out will gush the aqueous humour.

Having once made a small breach in the ring, the whole of the anterior flap can be easily reflected by keeping it well on the stretch, and assisting the process of tearing every now and then by the scalpel. When the dissector has gone right round, he will then have torn through the origin of the ciliary muscle.

The anterior flap (consisting of the cornea and the front part of the sclerotic) is now to be turned back upon its hinge just as we open a hunter-watch.

We now see exposed the iris (with pupil in centre, through which we see the lens), at the periphery of which we see the torn edge of the ligamentum pectinatum.

Beyond this we see the ciliary muscle forming a white ring (the annulus albidus), and beyond this again we see the choroid, the *venæ vorticosæ* of which can be readily made out. Finally, running up between the choroid and sclerotic we see the ciliary vessels and nerves, some of which will have been cut across while others can be traced into the ciliary muscle.

The eye is now to be held in the left hand with the free flap towards the dissector. The posterior pole is to rest on the fingers and the free flap is to be held back by the thumb. An aneurysm needle is next to be introduced with its concavity looking upwards under the iris (on the opposite side of the eye to the hinge) and its point pushed away from the dissector. Its progress is soon stopped by the union of the ciliary processes with the suspensory ligament of the lens. By carefully pushing onwards the needle, and keeping its point slightly downwards as well as away from himself, the dissector will be able to separate the ciliary processes from the "beds" of the subjacent suspensory ligament which receive them. This separation should be effected for about one-fourth of the circle, after which the aneurysm needle is to be withdrawn, and one blade of the scissors introduced in its place. A cut is then to be made on each side of the part that is free towards the posterior pole (*i.e.*, along two meridians). The flap so obtained is next to be turned back, when there will be displayed on its under surface the ciliary processes.

This completes the dissection, and the eye should next be placed in "normal salt" solution. The ciliary processes may be better displayed if we now remove the pigment from the region of the free flap by gently rubbing it between a finger and thumb, of course keeping them beneath the water all the time. The eye should then be placed in clean salt solution, with the view of studying the parts now exposed.

SOME RECENT AND SOME NEW HISTOLOGICAL METHODS.

By WILLIAM STIRLING, M.D., Sc.D., *Brackenbury Professor of Physiology and Histology in The Owens College, Manchester, and Professor in Victoria University.*

(From the Physiological Laboratory of The Owens College, Manchester.)

Dry Method for Blood-Platelets.—The methyl-violet and osmic acid methods for obtaining these bodies are well known. One of the most convenient methods, however, is that of Hayem.¹ Clean a slide, sterilise it in the flame of a Bunsen burner, and allow it to cool. Obtain a drop of blood from the finger in the usual way, and rapidly transfer a little to a slide. With the edge of another slide rapidly spread the blood into a very thin film on the sterilised slide. Move the slide to and fro in the air until the film dries. The whole process should not occupy more than four seconds. Cover the film with a cover-glass, and cover the edges of the latter with paraffin wax. The blood-platelets are readily seen in the dry film of blood amongst the other corpuscular elements.

Staining of Fibrin.—In a preparation of blood Spiller's purple is frequently used to stain fibrin. A much better method is that of Weigert, although the technique of the process is not so simple. It requires a little care, and after one or two attempts one readily succeeds. Suppose one has to deal with a thrombus in a vein, or a lung affected with acute croupous pneumonia. The tissue is hardened by the ordinary methods, and sections are made say by freezing. Stain a section for a minute or two in the following fluid :—

Gentian-violet (5 per cent.),	. . . . .	44 c.c.
Aniline oil,	. . . . .	1 c.c.
Alcohol (96 per cent.),	. . . . .	6 c.c.

Place the section on a slide and remove as much of the stain as possible, by pressing on the section—and do this rather firmly—several folds of unsized printing paper. Ordinary filter paper or blotting paper must not be used, as the fibres of the paper adhere to the preparation. Pour on the section a small quantity of a solution of iodine (iodine dissolved in water containing 5 per cent. of potassio iodide). The iodine solution rapidly decolorises most of the stained parts. A similar solution is used in Gram's method of staining certain bacteria. Remove the iodine solution in the same way as directed for the removal of the gentian-violet.

Pour on the section a mixture of equal parts of aniline oil and xylol. This is a clarifying medium, and will clarify sections even when the latter have not been previously dehydrated by alcohol. Move the fluid over the preparation by tilting the slide from side to

¹ *Du sang et de ses altérations anatomiques.* Paris, 1889.

side, much as a photographer moves a fixing fluid on a photographic plate. Remove the clarifying medium, and add a fresh supply of the same. It clarifies the section, and at the same time removes some of the dye. As long as there is a trace of white in the preparation, the latter is not completely dehydrated. As the aniline oil would ultimately destroy the colour of the section, remove with unsized paper as before as much as possible of the clarifying reagent, and wash the section several times with xylol. Mount the section in xylol-balsam; all the fibrils of fibrin have acquired a violet colour and the other tissues are either unstained or only feebly stained.

Isolated Epithelial Cells.—The methods employed are exceedingly numerous, including dilute alcohol and very dilute solutions of chromic acid, or certain of the salts of the latter. Every histologist is familiar with the valuable properties of Ranvier's dilute alcohol. For epithelial structures, however, which are rather thick and dense, and where isolated cells are required for a large class of students, the following plan of Schiefferdecker¹ is most convenient. It is applicable to all forms of epithelium, but is specially valuable for stratified squamous epithelium, *e.g.*, of skin or mucous membranes. After experimenting with a great variety of tissues covered with stratified squamous epithelium, I find that the hard pad on the jaw of the sheep or ox answers admirably. Epithelial cells of all shapes, and prickle cells as well, can be readily isolated by the method. I am in the habit of isolating the cells, and keeping them when isolated in glycerine jelly. The cells may be stained beforehand, and kept ready stained in glycerine jelly. A drop of the glycerine jelly, when melted, contains a large number of isolated cells.

Make a cold watery extract of the "pancreaticum siccum" of Dr Witte, of Rostock. This is supplied in commerce as a greyish-brown powder, which has marked digestive properties. It is prepared from the pancreas, and contains the same enzymes as the pancreas itself. Filter the extract, and into it place small pieces of the object to be digested. Cover the vessel, keep it at a temperature of 37° to 38° C. for three or four hours. Wash the tissue in water, and preserve it in a mixture of equal parts of glycerine, water, and alcohol (96 per cent.). After it has been macerated for a short time in this fluid, on scraping the surface isolated cells are detached, and can readily be examined, as they are, or after being stained by any of the staining reagents in ordinary use.

Mitosis in the Salamander.—Considering the importance of mitosis, and the fact that the process is described in every text-book of histology, one would think that a practical acquaintance with the various appearances should be within the reach of students. It is well known that the young stamens and unripe ovaries of certain plants yield excellent mitotic figures, and such tissues may be used. In some respects the study of the process is more difficult in animal textures. Keep the young of the Salamander until they are 1 to 1½ inch in length, but they must be well fed, else the mitotic

¹ *Zeitschrift f. wissen. Mikroskop.*, vol. iii. p. 483, and *Das Mikroskop. u. d. Methoden.*, &c., by Behrens, Kossel, and Schiefferdecker, Braunschweig, 1889.

figures are not well developed. Harden them in one-sixth per cent. chromic acid, or Flemming's mixture. Make transverse sections across the tail, so as to include the epithelial covering. Fix the sections on a slide with any of the recognised "fixatives," e.g., oil of cloves and collodion, or white of egg and glycerine. Stain the sections in saffranin, treat them with acid-alcohol, and mount them in balsam. In almost every section the student will obtain nuclei in various phases of mitotic division, so that in a few sections he will possess nearly a complete cycle of mitotic changes.

For surface views the epithelium covering the gills or cornea of the young Salamander are also to be recommended.

Mitosis, however, is not so readily demonstrated in mammalian tissues, partly because the histological elements are smaller, and therefore it requires a much higher power to see the changes in the nuclei. In the amnion of the Rat, however, as pointed out by Solger,¹ mitotic figures are fairly readily obtained thus:—The uterus is cut out of a pregnant white rat just killed, and placed in a saturated watery solution of picric acid. The uterus is opened under the picric fluid, and the amnion liberated. The whole amnion is hardened for twenty-four hours in picric acid, and after thorough washing with alcohol, it is hardened in the various strengths of alcohol (beginning with 70 per cent.), and the membrane is then stained with Ehrlich's acid, hæmatoxylin, diluted one-half with water, and mounted in balsam. In this preparation the mitotic figures are fairly readily seen, but they are neither so large as in the Salamander, nor so small as those in the spleen or lymphatic glands. Still the mitotic figures are of fair size, the interval between the two poles of diaster being 0·01322 mm. The amnion is sufficiently large to enable one to get a considerable number of preparations from a single fœtus. The length of the fœtus from which the amnion is taken should be about 1·8 cm. to 2 cm. The mitosis shown here is in the epithelial cells covering the amnion. I have had the privilege of inspecting Professor Solger's preparations, and on repeating the process I find it to be one quite within the range of subjects that may be given to advanced students of histology.

Method of Martinotti and Resegotti for Mitosis.—The tissue, e.g., a rapidly growing tumour, a freshly excised wart or papilloma, are hardened in absolute alcohol. Stain the sections in a watery solution of saffranin. The decolorisation in this method is accomplished by means of a hydro-alcoholic solution of chromic acid, made by adding eight parts of alcohol to one part of a one-tenth per cent. solution of chromic acid. By exposing the section for a short time to the action of this fluid, all the parts are decolorised except the chromatin fibrils of the nuclei. The sections are clarified in oil of bergamot and mounted in xylol-balsam. The complete process is the following:—The tissues are fixed in absolute alcohol. The sections are stained for five minutes in a saturated watery solution of saffranin, and are then transferred to the hydro-alcoholic solution of chromic acid to differen-

¹ "Säugethier-Mitosen im histolog. Kursus.," Schultze's *Archiv*, xxxiii. p. 517.

tiate the colour. The sections remain in this fluid for about one minute or less, and are then dehydrated and clarified, as already described.¹

By this method the chromatic filaments and the nucleoli are coloured of a bright rosy tint, while the protoplasm and intercellular substance remain uncoloured. Resting nuclei are feebly stained of a pale rosy tint. The hydro-alcoholic chromic solution should be prepared each time it is required.

Resegotti has studied the action of a large number of aniline dyes on mitotic figures. The best results, with tissues hardened in absolute alcohol, are obtained by double staining with methyl-violet or dahlia with eosin or acid fuchsin. The sections are first stained in a weak solution of methyl-violet, and then in a very dilute alcoholic solution of eosin. In this process the chromic acid differentiating medium is omitted.²

Methods of Staining Elastic Fibres.—Considering the great importance of elastic fibres in the structure of so many organs, it is not to be wondered at that many methods have been proposed for facilitating the study of this tissue. Some years ago, relying on the indigestibility of elastic fibres by gastric juice, I devised a method of artificial digestion, whereby the whole fibrous tissue was dissolved by a peptic digestive fluid, leaving the elastic fibres unaffected.³ Others have gone on a different principle, notably Unna,⁴ Lustgarten, who used Victoria blue (24 hours),⁵ Martinotti, and Herzheimer. I have tried all the recently described methods, but the two which seem to yield the best results are those of Herzheimer and Martinotti.

*Herzheimer's Method for Elastic Fibres.*⁶—Sections of a tissue or organ containing elastic fibres, and previously hardened in Müller's fluid, are placed for a few minutes in an alcoholic solution of hæmatoxylin, to which is added a few drops of a saturated solution of lithium carbonate. The sections become quite black, and are transferred for five to twenty seconds to dilute tincture of perchloride of iron. This rapidly decolorises all the tissues except the elastic fibres, which remain of a blackish or bluish-brown tint. The sections are mounted in xylol-balsam. This method is very good for arteries and for the elastic fibres in the trachea and bronchi, and also for the elastic fibres of the cutis vera.

*G. Martinotti's Method for Elastic Fibres.*⁷—This seems to me to be one of the best methods for staining elastic fibres. The tissue or organ is hardened in .2–.25 per cent. chromic acid, and afterwards

¹ "Ulteriori esperienze sulla coloraz. d. figure cariocinet," *Giornale della R. Accad. di Med.*, 1888, Nos. 6, 7.

² "Un metodo per rendere evidenti le fig. cariocinet," by G. Martinotti and L. Resegotti, *Zeits. f. wiss. Mikros.*, iv. p. 326.

³ "A New Method of Preparing the Skin for Histological Examination," *Jour. Anat. and Phys.*, 1875.

⁴ *Monatsch. f. prakt. Dermat.*, B. ii., 1883 and 1886, p. 242.

⁵ *Wien. Med. Jahrb.*, 1886.

⁶ *Fortschr. d. Med.*, Bd. iv. p. 785.

⁷ "Un metodo semplice per la colorazione delle fibre elastische," *Zeitsch. f. wiss. Mikros.*, iv. p. 31.

in alcohol. Sections, after thorough washing, are steeped in an alcoholic solution of saffranin—0 for twenty-four or forty-eight hours or longer, in fact, they take no harm from prolonged immersion in saffranin, as any surplus dye can be washed out of the section by means of acid-alcohol, i.e., alcohol containing 1 per cent. of hydrochloric acid. The solution of saffranin used is 5 grammes of saffranin dissolved in 100 c.c. alcohol, to which is added next day an equal volume of water, or thrice the volume of water may be added. I was somewhat surprised at first on trying this reaction to find that I did not succeed. Ultimately I found, however, that the cause of my want of success was due to the saffranin which I used, and which I procured in this country. On procuring a sample of saffranin—0, I at once obtained the result described by Martinotti, viz., coloration of the elastic fibres of a bluish or blackish-purple tint—or the fibres may be quite black—while certain of the other elements, e.g., the nuclei, are stained red, and other elements diffuse red tint. The sections, over-stained in saffranin, are partially decolorised in acid-alcohol, and then mounted in xylol-balsam.

This is a most excellent method. I have used it specially for the elastic fibres in arteries. By this method the student gets a good idea of the distribution of the elastic structures—membranes and fibres—in the various coats of an artery. It is also most serviceable for sections of the lung. In this case the elastic network between the air-vesicles can be traced quite readily, and so can the elastic fibres in the deep layer of the pleura. One can readily trace the connection of the latter system of elastic fibres—epi-pulmonary—with the intra-pulmonary system of elastic fibres. Similarly, sections—transverse and longitudinal—of the trachea and bronchi yield good pictures. It is also very serviceable in the case of the spleen, revealing the extent and ramifications of the elastic fibres in the trabeculae and in the intra-splenic arteries and veins. By it also the distribution of elastic fibres in the cutis vera is made fairly distinct, although we still require a good description of the arrangement of the elastic fibres in the cutis vera and its papillae.

The coloration may be effected more rapidly by keeping the sections in the saffranin solution at a temperature of 37–38° C. for five hours or so.

Ferris¹ finds that even tissues hardened in absolute alcohol give the reaction, provided the sections are kept for at least five hours in a watery solution of chromic acid (1:1000) at a temperature of 37° C. or thereabout. They are then washed and stained in saffranin.

Elastic Fibres in the Lung.—I have devised the two following methods, which give good results:—Make thin sections of a dried and distended lung, and stain the sections on a slide with very dilute magenta. Care must be taken that the dry sections do not curl up, which they readily do when fluid is applied to them. Remove the

¹ "La colorazione d. fibre elastiche coll' acido cromatico e col. saffranin," *Giorn. della R. Accad. d. Med.*, 1888, No. 6-7.

surplus magenta and allow the section to dry completely on the slide. When the section is completely dry, add a drop of balsam and cover the preparation. The elastic fibres are stained red and their distribution and arrangement in and between the walls of the air-vesicles can be seen distinctly.

Instead of magenta methyl-violet may be used. The sections are then clarified by a mixture of aniline oil and xylol, and mounted in balsam.

Sarcolemma of Striped Muscle.—The usual plan is to direct that a piece of muscle be teased in distilled water, so that a bleb may be formed at one or more parts on the surface of the fibre. This method is by no means so very successful, and I daresay most teachers of Practical Histology have experienced some difficulty in enabling every student to secure a good preparation. A far better plan is that of Solger.¹ Place small pieces of fresh muscle in a saturated solution of ammonium carbonate (*saturated in the cold*) for a few minutes (3–5). Tease it slightly. It may remain in the fluid with advantage for a longer time. The sarcolemma is rapidly raised in the form of a clear bleb for a considerable distance along the course of the fibres, and there is not unfrequently here and there a small quantity of sarcoglia adhering to its under surface. The reaction seems to succeed better on animals (frogs) that have been kept in confinement for some time.

To see the *ruptured sarcous substance* and the sarcolemma stretching between the ends of the ruptured fibre, one of the best methods is the following:—Tease out a small portion of a fresh striped muscle in normal saline and place a hair—preferably from the beard—across the direction of the fibres on the slide. Apply a cover-glass and press the latter down firmly on the preparation. The flattened hair ruptures the fibres, the sarcous substance retracts, and the course of the hair—after the latter is removed—is marked by a line showing the sarcolemma of the individual ruptured fibres.

Muscle Discs.—The usual plan is to place dead muscle for several days in .2 per cent. hydrochloric acid. This is often not a satisfactory method. I find that maceration for several hours in a saturated solution of ammonium carbonate rapidly effects the transverse cleavage of a striped muscular fibre into muscle discs.

Heidenhain's Method for Glands.—This method is applicable to all secretory glandular structures and to connective tissue as well. One obtains very instructive preparations of the salivary glands and pancreas by this method. The gland is hardened in alcohol, and small pieces of the hardened gland are placed for six to eight hours in 10 c.c. of 0.5–1 per cent. watery solution of hæmatoxylin; and then for an equal period in a few c.c. of .5 per cent. solution of potassic bichromate or 1 per cent. watery solution of alum. The pieces look quite black when they are removed from the hæmatoxylin fluid. In this method the change of colour in the hæmatoxylin caused by the chromium salt or the alum is effected within the tissue itself. In

¹ "Kohlensaures Ammoniak, ein Mittel zur Demonst. d. Sarkolemmas," *Zeits. f. wissen. Mikros.*, vi. p. 189.

the submaxillary gland, for example, the nuclei are stained of pleasant bluish-black tint, the cell-substance is steel grey, while the demilunes stand out distinctly.

This method does also very well for serous salivary glands such as the parotid, and also for the pancreas.

Heidenhain,¹ I think, has recently altered somewhat the method for the better. The tissue, hardened in alcohol, or a saturated solution of picric acid, is placed for twelve to twenty-four hours in $\frac{1}{2}$ per cent. of a watery solution of hæmatoxylin, and subsequently in .5 per cent. solution of potassic chromate, in which it is bleached somewhat. By employing small pieces of tissue a differentiation of the chromatin can be obtained.

Recently a large number of new methods have been recommended for the study of nerve fibres. While the ordinary method with silver nitrate does very well for Ranvier's crosses, I think the following method is preferable; besides it has the advantage of revealing very sharply the alternate brown and clear transverse lines in the axial cylinder known as Frommann's lines:—

Ranvier's Crosses and Frommann's Lines.—Place a fresh nerve in .5–1 per cent. silver nitrate solution for twenty-four hours, and keep it in the dark. After the expiry of this time remove the nerve, wash it in water, and expose it to light for two to three days in equal parts of formic acid, glycerine, and water, and preserve it in glycerine. The crosses are sharply defined, and so are Frommann's lines; and if an axial cylinder happen to be detached from its position within a nerve fibre, the biconical swelling at the node can be readily seen.

Neuro-Keratin Network and Axis Cylinder.—Kühne used tryptic digestion for revealing the presence of the neuro-keratin network in the myelin of medullated nerve-fibres. This is not a method capable of being readily employed by the average student. The following method of Platner yields good results:²—Place a fresh sciatic nerve—e.g., of a Frog—in a dilute solution of ferric chloride, consisting of—

Liquor ferri perchloridi,	. . .	1 part.
Distilled water or spirit,	. . .	3–4 parts.

Leave the nerve in this fluid for three or four days. Wash every trace of the iron salt out of the preparation. This can readily be ascertained by means of the thiocyanate test. Preserve it in alcohol. Place small portions of the nerve in a saturated solution of dinitro-resorcin in 75 per cent. alcohol. This unites with iron in the tissue, and gives a very durable green tint. Alizarin employed in the same way gives a violet colour.

Tease a fragment, dehydrate it in alcohol, and mount it in xylol balsam.

This is an excellent method. The axis cylinder has a green colour, and stands out sharply. It can be traced with ease through several inter-annular segments. The nodes of Ranvier are also sharply defined, while a network of fibres in the myelin, corresponding, according to

¹ *Arch. f. mik. Anat.*, Bd. xxvii. p. 838.

² *Zeits. f. wissen. Mikros.*, vi. 186.

Platner, to the neuro-keratin network of Kühne, is stained green. The method also succeeds with nerves hardened in Müller's fluid or picro-sulphuric acid.

Transverse Markings on Axis Cylinders and Nerve-Cells.—The existence of alternate dark and clear or lighter brown transverse markings, known as Frommann's lines, on the axial cylinders of cerebro-spinal nerves is well known; but, judging from the ordinary text-books, the existence of similar markings on the axis cylinders of the central nervous system, and also on the nerve-cells of the spinal cord, does not seem to be so well known. This is all the more remarkable considering how readily they can be prepared. These striæ are so regular in their arrangement as to remind one at the first glance of the alternate clear and dim discs of striped muscle. Five years after the appearance of Frommann's¹ paper, Grandry² described a method for demonstrating these lines. He used the spinal cord of the ox and the sciatic nerve of the frog. The organs must be quite fresh, and placed in the silver solution immediately after death. The objects are placed in silver nitrate solution (1:400), and kept in the dark, at the ordinary temperature, for four to five days. After this they are exposed to daylight in the same solution for two to three days. Fragments are teased in acidulated glycerine.

The transverse striation on the axis-cylinder is regular, and is composed of alternate dark (brown) and clear (or very faintly brownish) stripes, as if the silver had acted on one part and not on the other; the brown stripes have a certain breadth, which is not quite constant along the course of the fibre, while the distance between the brown bands, i.e., the clear part, may also vary at different parts of the cylinder. The intermediate or clear part is either completely colourless or faintly tinged with brown. Both Frommann and Grandry found that longitudinal striation was occasionally to be observed on the same axis-cylinders on which the transverse markings were distinctly seen.

On employing the same method for the large multipolar nerve-cells of the anterior cornea of the grey matter of the spinal cord of the ox, only leaving the tissue for a longer time in the staining fluid, Grandry found similar transverse markings on the nerve-cells. The finer striæ appeared homogeneous, but the larger brown ones appeared to be composed of an aggregation of brown or black grains united together. The striæ exist only on the body of the cells and its processes, but they do not occur on the nucleus. Longitudinal striation also exists in the cell. As to the significance of this transverse striation, some observers, such as H. D. Schmidt³ and R. Arndt,⁴ say that they are due to the structural properties of the axis-cylinders; others

¹ "Zur Silberfärbung der Axencylinder," *Virch. Arch.*, xxxi.

² "De la structure intime du cylindre de l'axe et des cellules nerveuses," *Journal de l'Anat. et de la Physiol.*, de C. Robin, Paris, 1869. See also Schwann, *Bulletin de l'Acad. des Sciences de Belgique*, 87^e Année, 2^e Serie, vol. xiv. p. 23.

³ "On the construction of the Dark or Double-bordered Nerve-Fibre," *Monthly Mic. Jour.*, xi. p. 200.

⁴ "Etwas über die Axen-Cylinder der Nervenfasern," *Virch. Arch.*, vol. lxxviii.

e.g., Boveri and Schiefferdecker, regard them as artificial productions.

To reveal these markings, the best method is that of Jakimovitch.¹ The strength of the silver nitrate solution varies from .25-1 per cent., according to the nature of the tissue. The .25 per cent. solution is employed for fibres in the central nervous system—.5 per cent. for peripheral nerves and 1 per cent. for nerve-cells. Very small parts of the perfectly fresh tissue are placed in a large quantity of the silver solution and kept in darkness. After twenty-four hours, the fluid being renewed several times in the interval, the pieces are well washed in water and exposed to light until they become brown. The tissue is then placed in the following mixture, and exposed to the light for several days—

Formic acid,	.	.	.	1 part
Amylic alcohol,	.	.	.	1 part
Water,	.	.	.	100 parts.

In this fluid the tissue becomes somewhat more transparent, as part of the reduced silver is redissolved by the acid, hence it is necessary to change the solution from time to time. When all the silver that can be dissolved has passed into solution, what remains assumes a brownish tint. For Frommann's lines or axis-cylinder so long a time is not required as for nerve-cells. In the case of the latter, the object is left in silver nitrate for forty-eight hours, and five to seven days in the acid fluid. The preparation is mounted in dilute glycerine.

In order to obtain the striation, the nerve-tissue should be as fresh as possible, preferably from a freshly-killed animal. Grandry gives the limit as six hours after death, after which, according to him, the experiment does not succeed; but, in the case of the spinal cord of the ox, I have succeeded with a cord removed twelve hours after death, but this applies to the axis-cylinders only. In some cases the clear bands are broader than the dark bands, and in other cases the reverse is the case. According to Jakimovitch these markings traverse the whole thickness of the axis-cylinder, and have nothing to do with the axilemma. On this and other grounds he thinks that the axis-cylinder is made up of fibrils consisting of "nervous particles," alternate discs, differing in chemical constitution, and therefore behaving differently to silver nitrate. No such transverse striation, however, is to be obtained with non-medullated nerve-fibres.

To see the transverse striation on the cells, the tissue is placed in a stronger solution of silver and exposed for a longer time to light. So far only the large multipolar nerve-cells of the grey matter of the spinal cord have been shown to exhibit transverse striations by this method.

Dry Preparations of the Spinal Cord.—On a slide stain a transverse section of a spinal cord with methylene blue. Remove the surplus dye and allow the section to dry on a slide. When it is thoroughly dry add a drop of balsam and cover the preparation. There is a

¹ "Sur la structure du cylindre-axe et des cellules nerveuses," *Jour. de l'Anat. et de la Physiol.*, xxiv., 1888, p. 142.

sharp differentiation of the individual parts of the section. The cells are shrunk somewhat, but otherwise the appearance of the section is not greatly altered by the process, and the result is a preparation agreeable to the eye.

*Golgi's Method for Central Nervous System.*¹—This method only requires to be tried, and satisfactory results are obtained with a little care. It is one which can readily be practised with success by a student. Harden the brain and spinal cord in Müller's fluid or 2 per cent. potassic bichromate for six weeks or longer. Small pieces of the hardened brain are placed in a small quantity of a quarter per cent. silver nitrate, and washed in this until all the surplus silver on the surface of the piece of tissue is transformed into silver chromate. The pieces are afterwards placed for forty-eight hours or longer in .25 per cent. silver nitrate, and the whole kept in the dark. A half per cent. solution of mercuric chloride may be used instead of the silver, but the latter yields results more speedily. Harden the tissue in alcohol, make moderately thin sections from the surface. The first section is almost certain to contain a large number of black patches of deposited silver, but the next section will yield good results. Care must be taken that the plane of section runs parallel to the direction of the cells and their processes.

In properly prepared sections which are mounted in balsam without a cover-glass being applied, one can see the nerve-cells and their finest processes quite black, and one realises the wealth of branched processes possessed by cerebral, cerebellar, and spinal nerve-cells in a way that is not possible by any other method. Sometimes it happens that the silver is largely deposited on the blood-vessels, so that in sections of the spinal cord one can readily trace the distribution of the spinal vessels within the medulla by the blackened deposit which exactly follows the distribution of the blood-vessels.

¹ *Sulla fina anatomia degli organi del sistema nervoso*, Milan, 1876.

Notices of New Books.

The Anatomy of the Central Nervous Organs in Health and Disease.
By Dr Heinrich Obersteiner. Translated, with Annotations and
Additions, by Alex. Hill, M.A., M.D. London: Charles Griffin
& Co., 1890.

DR OBERSTEINER'S treatise on the central organs of the Nervous System has been recognised as an excellent *résumé* of the present state of knowledge on this important branch of anatomy. Dr Hill, by his admirable translation, has brought the work within reach of those who do not read German, and he has added to the value of the translation by the addition of new matter, and by several useful criticisms.

Lectures on Nervous Diseases from the Standpoint of Cerebral and Spinal Localisation. By Ambrose L. Ranney, M.D. Philadelphia: F. A. Davis, 1888.

THIS work, although mainly clinical and practical in its scope, is based upon the most recent investigations into the anatomy and physiology of the nervous system. We would direct attention to the ingenuity and novelty of many of the diagrams which the author has employed to illustrate the intricate mechanisms which have to be studied in this special field of medical practice.

Über die Blutgefäße des menschlichen Rückenmarkes. Von Prof. Dr Heinrich Kadyi. Lemberg, 1889. 4to, pp. 152, 10 plates.

AN important memoir on the descriptive anatomy of the blood-vessels of the spinal cord in man, with beautifully coloured plates.

Das Gefäß und Periphere Nervensystem des Gorilla. Von Dr Paul Eisler. 4to, pp. 78, 9 plates. Halle, 1890.

THIS is the first and only memoir as yet published, in which a systematic description of the vascular and peripheral nervous system of the Gorilla has been given. The plates are well executed.

Memoir on the Anatomy of the Humpback Whale (Megaptera longimana). By John Struthers, M.D. 8vo, pp. 188, 6 plates. Edinburgh, 1889.

THIS is a reprint of a series of articles which appeared in successive numbers of this *Journal*, 1887-89.

A Text-Book of Human Anatomy, Systematic and Topographical, including the Embryology, Histology, and Morphology of Man, with Special Reference to the Requirements of Practical Surgery and Medicine. By Alexander Macalister, M.D. London: Charles Griffin & Co., 1889.

AN important treatise on an old subject by one of the best known and most accomplished of living teachers. Within the compass of 748 pages, interspersed with 816 woodcuts, the author has condensed an account of the anatomy of the human body in its ordinary descriptive details, its embryonic evolution, the structure of its tissues, and its practical applications to the art of healing. The work abounds therefore in information of a varied kind, and if mastered by the student should give him, when combined with an efficient course of practical instruction, a competent knowledge of human anatomy, both in its scientific aspects and in its applications to medical and surgical practice.

A Text-Book of Animal Physiology. By Wesley Mills, M.A., M.D., Professor of Physiology in McGill University, Montreal. New York and London: Appleton & Co., 1889.

IN this text-book the subject is treated from the point of view of comparative physiology, and in addition to the topics which are ordinarily discussed in a physiological text-book, questions of organic evolution, of heredity, and of the transmission of acquired characters, are considered. The author is no blind follower of those who have preceded him in speculations on these topics, but looks at them in the light of his own observations and opinions. There is much healthy criticism in the book, which is worthy of perusal by teachers as well as students.

A Text-Book of Human Physiology. By Austin Flint, M.D. Fourth edition, entirely rewritten. London: H. K. Lewis, 1888.

THE continued advances in physiological science have compelled the author to a large extent to rewrite his text-book, so that, as compared with the third edition, published in 1880, this is almost a new work, which is as readable as its predecessors.

Special Physiology: including Nutrition, Innervation, and Reproduction. By John Gray M'Kendrick, M.D., F.R.S. Glasgow: Maclehose & Son, 1889.

By the publication of this volume Professor M'Kendrick has completed his text-book on physiology, the first volume of which was published some time previously. The student will find in it an excellent *résumé* of the subject, and the section on Innervation is especially worthy of perusal.

Outlines of Practical Histology. By William Stirling, M.D.
London: Charles Griffin & Co., 1890.

A COMPACT manual of the subject, which embodies an account of the most recent methods.

Illustrations of Zoology, Invertebrates and Vertebrates. By W. Ramsay Smith, B.Sc., and J. Stewart Norwell. Edinburgh and London: Pentland, 1889.

IN this work the authors have illustrated, by diagram or drawing, the structure of a number of Vertebrates and Invertebrates. The forms they have selected are such as the student may usually obtain without much difficulty for dissection, and the work is thus a useful adjunct to a course of practical zoology.

Memoirs and Memoranda on Anatomy. By John Cleland, M.D., F.R.S., John Yule Mackay, M.D., and Robert Bruce Young, M.B.
London: Williams & Norgate, 1889.

THIS work is written conjointly by Professor Cleland and his assistants in the Anatomical Department in the University of Glasgow. It contains a number of articles on various points in anatomy, both human and comparative, several of which treat of teratological subjects.

A Manual of Anatomy for Senior Students. By Edmund Owen, M.B., F.R.C.S. London: Longmans, 1890.

IN this manual the author has limited himself to such a description of the anatomy of the human body as chiefly concerns the physician and surgeon. He has avoided unnecessary descriptive details, and has gathered together a quantity of information which the student will find useful in the application of his anatomical knowledge to his work in the wards of a hospital and in private practice.

The Human Foot, its Form and Structure, Functions and Clothing.

By Thomas S. Ellis. London: Churchill, 1889.

AN interesting work on the human foot, in which the author explains its mechanism, and gives the rules which he considers should be attended to in the construction of boots and shoes.

La Glycogénie Animale. Par le Professeur J. Seegen, de Vienne; traduction par le Dr L. Hahn. Paris: G. Masson, 1890.

THIS work consists of a course of fifteen lectures, in which the author considers the question of the glycogenic function of the liver; its presence in the blood and the muscles; the part which sugar plays in the economy, and the elimination of sugar by urine. In the fifth lecture he gives the results of his own experiments.

Aphasia, or Loss of Speech, and the Localisation of the Faculty of Articulate Language. By Frederic Bateman, M.D., F.R.C.P., Senior Physician to the Norfolk and Norwich Hospital, Visiting Physician to the Bethel Hospital. Second edition, greatly enlarged. London: J. & A. Churchill.

THIS book is a second and greatly enlarged edition of a treatise published some years since. Since that time, the author's attention has been constantly directed to the study of aphasia and the localisation of the faculty of speech, and he has endeavoured to bring the work up to the present state of our knowledge of the intricate subject of which it treats; so much fresh matter has been added as to constitute it rather a new work than a revised edition of a former one.

Portrait of John Hunter.

MR H. K. LEWIS, of 136 Gower Street, London, has reproduced, by an autotype process, Gellers' fine mezzotint engraving of Reynold's famous portrait of Hunter in the Royal College of Surgeons of England. Those who may wish to possess a portrait of the great anatomist and surgeon cannot do better than acquire this autotype.

INDEX.

- ACROMEGALY**, 475.
Albumen, 288.
Amnion in Chick, 1.
Anomalies, Vascular, 69, 182, 423; **Digital**, 167; **Reproductive Organs**, 218, 369; **External Pterygoid Muscle**, 567.
Anodon, Tumours in, 307.
Arctic and Sub-Arctic Water-Birds, 89, 169, 543.
Arteries, Motion of Blood in, 434, 592.
Articular Surfaces, Influence of Posture on, 210.
Axillary Muscles, 52.
Axis, with Separate Odontoid, 358.

BIRDS, Arctic and Sub-Arctic, 89, 169, 543.
Blood, Motion of, 434, 592.
Bones, Lacrymal, 849; **Odontoid**, 358.
Book Notices, 472, 611.
Brain, Intraparietal Sulcus, 135; **Complete Fissures of**, 309.
Brodie, C. Gordon, Ligaments of Shoulder, 247.

CAGNEY, JAMES, Vertebral Column in Hanging, 585.
Carrier, E. W., Fate of Notochord, 573.
Cell Theory, 253.
Chick, Proamnion and Amnion, 1.
Cystin, 346.
Cleland, John, Fibro-plates and Discs, 373.
Coagulation of Albumen, &c., 283.
Cooke, G. H., Action of Stimuli on Muscle, 195.
Cunningham, D. J., Lumbar Spine, 117; **Eighth True Rib**, 127; **Intraparietal Sulcus**, 135; **Complete Fissures of Cerebrum**, 309.
Curare, 379, 509.

DELÉPINE SHERIDAN, Cystin Ferment, 346.
Delphinoid Stomach, 188.
Digits, Flexors of, 72; **Malformation of**, 167.
Douglas, K. M., Inguinal Hernia, 220.
Duggan, C. W., Coagulation of Albumen, 288.
Duncan, Horace, Eyeball, 599.
Dry Cover-Glass Preparations, 160.
Dwight, Thomas, Third Trochanter, 61; **Sternum**, 527.

ELEPHANT, Skin of, 493.
Ewart, J. C., Spiracles in Porbeagle Shark, 227.
Eyeball, 599.

FERMENTATION and Cystin, 346.
Fibro-plates, 373.
Frog, Hermaphroditism in, 213, 369.

GLAND, Prostate, 27, 236.
Globulin, 288.
Gorilla, Spine of, 42.
Giant Cells of Tubercle, 517.
Gray, R. W., Stomach of Narwhal, 188.
Greenfield, W. S., Malformation of Heart, 423.
Griffiths, Joseph, Prostate Gland, 27, 236.
Gustatory Organs, 85, 130, 156.

HANGING, Vertebral Column in, 585.
Haycraft, J. B., Coagulation of Albumen, 288.
Heart, Malformation of, 423.
Hereditary Malformations, 167.
Hernia, Inguinal, 220.
Hermaphroditism in Frog, 213, 369.
Hoorweg, J. L., Motion of Blood, 434, 592.
Howes, G. B., Kidney of Thornback, 407.
Humphry, G. M., Genu Valgum, 593; **Senile Changes**, 598.

IMBEDDING Tissues, 230.
Intervertebral Discs, 373.

JOINTS, Loose Bodies in, 360.

KARYOKINESIS, 274.
Kidney of Thornback, 407.

LACHRYMAL Bone, Varieties of, 349.
Latter, O. H., Abnormal Reproductive Organs, 369.
Ligaments of Shoulder, 247.
Liver, Abnormal Vessels of, 132.
Lumbar Spine, 117.
Lumbrical Muscles, 22.

MICROSCOPIC Technique, 160, 230, 601.
Muscles, Nerve Supply of, 22, 52; **Flexors**, 72; **Stimuli on Non-striped**, 195; **Transversalis**, 220; **External Pterygoid**, 567.
Mussel, Tumours in, 307.

- NARWHAL, Stomach of, 188.
 Neuritis, Retro-bulbar, 504.
 Nerve Supply of Muscles, 22, 52.
 Notochord, Fate of, 573.
- ODONTOID Bone, 358.
- PATTERSON, R. G., Loose Bodies in Joints, 360.
 Pharmacology, 379, 509.
 Pickering, J. W., Proamnion and Amnion, 1.
 Poland, John, External Pterygoid Muscle, 567.
 Porbeagle, Spiracles in, 227.
 Posture, Influence of, 210.
 Proamnion in Chick, 1.
 Prostate Gland, 27, 236.
- Raia clavata*, Kidney of, 407.
 Reproductive Organs, Abnormalities of, 213, 369.
 Ribs, Eighth True, 127.
 Right Handedness, 127.
 Robertson, W. R., Imbedding Tissues, 230.
 Rolleston, H. D., Abnormal Vessels to Liver, 132.
- SHEPHERD, F. J., Vascular Anomalies, 69.
 Shore, T. W., Proamnion and Amnion, 1.
 Shoulder, Ligaments of, 247.
 Shufeldt, R. W., Arctic and Sub-Arctic Water-Birds, 89, 169, 543.
 Sibley, W. K., Giant Cells of Tubercle, 517.
 Skin of Elephant, 498.
 Smith, W. R., Hermaphroditism, 218.
 Smith, Fred, Skin of Elephant, 493.
 Spiracles in Porbeagle, 227.
- Sternum, 527.
 Stimuli on Non-striped Muscle, 195.
 Stirling, Prof. W., Dry Cover-Glass Preparation, 164; *Histological Methods*, 801.
 Stomach of Narwhal, 188.
 Suture, Orbito-Maxillo-Frontal, 349.
 Symington, J., Spine of Gorilla, 42.
- THORNBACK, Kidney of, 407.
 Thomson, A., Posture and Form of Articular Surfaces, 210; Orbito-Maxillo-Frontal Suture, 349.
 Thomson, H. Alexis, *Asromegaly*, 475.
 Tillie, Joseph, Curare, 379, 509.
 Tissues, Imbedding, 230.
 Transversalis Muscle and Inguinal Hernia, 220.
 Trochanter, Third, 61.
 Tubercle, Giant Cells of, 517.
 Tuckerman, F., Gustatory Organs, 85, 130, 156.
 Turner, Sir W., Cell Theory, 253; *Os Odontoideum*, 358.
 Turner, W. A., Retro-bulbar Neuritis, 504.
- VASCULAR Anomalies, 69, 132, 423.
 Vertebral Column of Gorilla, 42; Bone and Cartilage in, 117; in *Hanging*, 585.
 Vitellin, 288.
- WILKIE, J., Malformed Digits, 167.
 Williams, J. W., Tumour in Mussel, 307.
 Wilson, J. T., Nerve Supply, *Variation* in, 22, 82.
 Windle, B. C. A., Flexors of Digits, 72.
 Woodhead, G. S., Stomach of Narwhal, 188.
- ZIPHOID Stomach, 188.

PROCEEDINGS OF THE
ANATOMICAL SOCIETY OF GREAT BRITAIN
AND IRELAND.

MAY 1890.

A MEETING was held in the Board Room of St George's Hospital, on Friday, May 30, 1890. Professor Humphry took the chair. Seventeen members were present.

The following gentlemen were elected members :—Professor J. T. Wilson and Mr F. E. Withers.

The following gentlemen were nominated for election at the next meeting :—C. H. Abbott, M.B. Lond., Assistant Demonstrator of Anatomy at St Thomas' Hospital, proposed by William Anderson, G. H. Makins, and F. G. Parsons ; George Gulliver, M.A., M.B. Oxon, Assistant Physician and Lecturer on Comparative Anatomy at St Thomas' Hospital, proposed by William Anderson, G. H. Makins, and F. G. Parsons.

Professor STEWART showed two specimens of the *Pineal Eye* from *Varanus salvator*.

Mr BLAND SUTTON showed a *Rabbit's Spine containing a Half Vertebra on the Left Side of the Lumbar Region*. The specimen is in the College of Surgeons' Museum.

Professor MACALISTER said it was not difficult to show double centres in human lumbar vertebra.

Mr THOMSON had seen a dumb-bell-shaped human lumbar vertebra pointing to the double ossification, but had never actually seen the two centres.

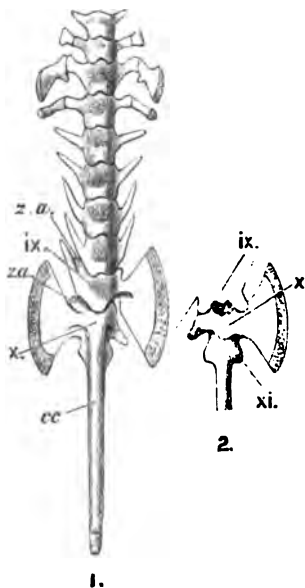
Professor G. B. HOWES mentioned that in all quadrupedal mammals the odontoid process had two ossifying centres in early extra-uterine life. He had only seen the deformity in this one specimen among many hundreds of rabbits.

Mr BLAND SUTTON showed sections of *Fallopian Tubes from Macacus rhesus*, and *Cervus eldi*, a Panolian deer. The specimens showed under the microscope branched projections into the lumen of the tube, with recesses between them. These, which in the adult form

longitudinal grooves down the tube, begin as pits by an involution of the mucous membrane like true glands.

Some difference of opinion was expressed as to the glandular nature of the recesses, and Mr Sutton promised to bring before a future meeting specimens showing the early stage of their development in the human fœtus.

Professor G. B. Howes exhibited the *Vertebral Skeleton of a Fire Toad (Bombinator, ? sp.)*, which he had received from his pupil, Mr Arthur C. Jones, resident in Davos Dörfli, and made the following remarks thereon. The specimen (♀) was captured at Canton St Gallen;



Bombinator (? sp.) abnormal sacrum (♀) × 2. Fig. 1. Entire vertebral column, ventral view. Fig. 2. Coccygeal portion of sacrum, dorsal view.

its seven anterior vertebræ and pelvic girdle were normal, but special interest centered in its sacrum. The vertebral column of all living anurous amphibia bears normally nine free vertebræ, with the exception of *Pipa*, in which the number is reduced to eight, most probably by the excalation of that answering to the second vertebra of other forms (v. Hering, *Morph. Jahrb.*, Bd. vi. p. 297) rather than by conrescence, as was formerly supposed. On the other hand, more than nine free vertebræ appear to have existed in some extinct Anura (cf. Portis, *Atti R. Accad. Sci. Torino*, vol. xx. p. 1173, 1885). Abnormal sacra have been described in the Anura by Götte (*Entwicklungsgesch. d. Unke*, Leipzig, 1875, taf. xix.); Bourne (*Quart. Jour. Micr. Sci.*, N.S., vol. xxiv. p. 83); Howes (*Anat. Anz.*, 1886, p. 277);

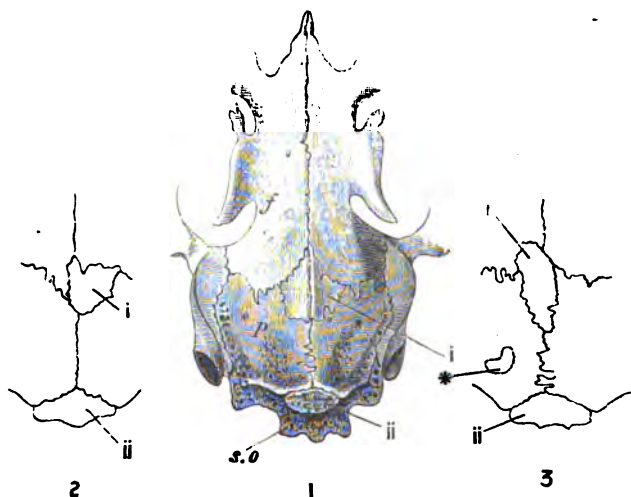
Morgan (*Nature*, vol. xxxv. p. 53); Sasserno (*Atti R. Accad. Sci. Torino*, vol. xxiv. p. 703), and others, and in the tailed Amphibia (*Menopoma*) by Huxley (art. "Amphibia," *Encyc. Brit.*, 9th ed., vol. i. p. 752 [cf. Lucas, *Americ. Nat.*, 1886, p. 561]). Conspicuous among the individual variations recorded are those in which, while the normal sacrum existed, the last pre-sacral vertebra had developed a sacral transverse process, whereupon there were present, on one or both sides as the case might be, two sacral vertebrae. This line of variation was especially interesting as showing an approximation towards a more marked condition of the same described by Walterstorff (*Jahrb. Naturwiss. Vereins. Magdeburg*, 1885-86), for the extinct *Palæobatrachus*, in which three sacral vertebrae were often, if not always, present—a culminating term in the amphibian series which Walterstorff would exalt to a family distinction.

The sacrum of *Bombinator* is known, from the researches of Boulenger (Walterstorff, *op. cit.*, 1886, p. 155), Sasserno (*cf. ante*), and others, to be subject to an exceptional degree of variation. In the individual example exhibited the sacral transverse process of the right side had become replaced in one derivative of the head of the potentially segmented urostyle or coccyx (*cc.*), the condition being the reverse of one described by Sasserno (*loc. cit.*, pl. xii. fig. 14), a gap in whose series was thus filled. This individual appeared to agree in its leading peculiarities with one briefly described by Camerans (*Atti R. Accad. Sci. Torino*, vol. xv. p. 448). In those *Anura* for which a post-sacral sacrum has been hitherto recorded, the assumption of a sacral function on the part of the tenth vertebra was found to be largely accompanied by the dismemberment of the latter from the head of the urostyle; in the specimen exhibited, however, as in some of Sasserno's examples, this had not taken place, wherefore a *coccygeal sacrum* had been formed. The only other features of interest in the specimen were the great enlargement of the right anterior zygapophysis of the ninth (normal sacral) vertebra, successional with one specially developed from the corresponding border of the coccyx (*z.a. z.a.*), at the point of origin of the abnormal sacral transverse process.

Professor Howes concluded by saying, that the fact that terrestrial vertebrata possessed of but nine free vertebrae, should exhibit variation in the same, of the nature to which he had alluded, was *really* remarkable; and he regarded Sasserno's discoveries as welcome testimony to the belief for which he had previously argued before the Society (this Vol., p. 420)—that extreme individual variation, as affecting individual organs, is most marked in specialised forms of life.

Professor G. B. Howes also exhibited and made some remarks upon the *Crania of Three Rabbits* (*Lepus cuniculus*), showing the presence of Wormian bones in the coronal and sagittal sutures. Such specimens are of rare occurrence, and Gruber found (in Man) but 43 of them in 10,000 skulls examined. He had been on the alert for examples for the last four years; as the skulls exhibited were the

only ones, out of some hundreds which had passed through his hands during the period named, which showed the peculiarities in question, and as no mention of the same is made either by Nathusius (*Die sogenannten Leporiden*, Berlin, 1876), Krause (*Anat. des Kaninchens*, Aufl. 2, 1884), or by authors of the more didactic laboratory hand-books, he considered it worth while to place the facts on record in the interests of the junior student. Of the three specimens exhibited, that which first came under his notice bore a bone on the right side only, details of which are given in the accompanying figure (fig. 2); having later acquired a skull in which the reverse obtained (fig. 3), he was expectant of meeting with one in which a paired condition might have occurred. Such a one fell to his lot after an interval of two years; and it will be seen that in it (fig. 1) the bones were, as nearly as could be, bilaterally symmetrical.



Lepus cuniculus. Skulls, showing inter-frontal bones (ossa anti-epileptica). Nat. size. *f*, frontal; *p*, parietal; *s.o.*, supraoccipital; *i*, inter-frontal bones; *ii*, interparietal.

Bones of the category under consideration have long been known in all leading orders of mammals; the only mention of such in the Leporines is that of Wenzel Gruber,¹ who has recorded (p. 26) in the variable Hare (*L. variabilis*) the presence of a single bone, the exact position of which he does not describe. The rabbits and hares are exceptional among placental mammals for the great specialisation and constancy of the characters and relationships of their interparietal (*ii*), the longer retention of its independence being characteristic of the Rabbit's skull as distinguished from that of the Hares (*cf.* Nathusius, *loc. cit.*, p. 29). Nathusius has shown

¹ *Mém. Acad. Imp. Sci. St Pétersb.*, t. xix., No. 9, 1873. For this reference Prof. Howes was indebted to Prof. Alex. Macalister.

that the interparietal may be, in the Leporine, occasionally paired and bilaterally symmetrical; Professor Howes had satisfied himself that the assumption of that condition has resulted from a bilaterally symmetrical mode of ossification such as is more constant in the *Cetacea* and some *Insectivora* (*Erinaceus*, *Microgale*, [Parker, *Phil. Trans.*, part i., 1885]) and as may be instituted for the lineally disposed supraoccipital under lateral expansion (*Cetacea*).

Commenting upon the facts mentioned, he drew attention to the resemblances between the paired condition of the os antiepilepticum and its intercalation between the frontal bones, as compared with the paired interparietal of Nathusius and its intercalation between the parietals. The first-named lay wholly within the area of the normal parietals, and he regarded them as dismembered portions of these bones, indicative of that process of fragmentation (of which one specimen [* fig. 3] appeared to show additional traces) which may in rare instances lead up (in Man) to their replacement in a tessellated series of Wormian bones.

Mr F. G. PARSONS showed an *Occipital Bone with a Process faceted to articulate with the Odontoid Process*.

Mr BLAND SUTTON remarked that Mr Arbuthnot Lane had brought forward evidence to show that cases such as this, and those of ankylosis in the same situation, were the result of pressure from weights carried on the head. He had himself found similar ankylosis in the bodies of oxen near Paris, where they are harnessed by the head.

Professor HUMPHRY reminded the meeting, on the other hand, that a spur occasionally grew downward from the anterior tip of the foramen magnum without articulating with the odontoid process. This could hardly be a result of pressure from above.

Mr F. E. WITHERS showed a *Popliteal Artery*, which at the lower border of the popliteus muscle divided into four branches, the anterior and posterior tibial, the peroneal, and the nutrient artery to the tibia. Also, an *Abnormal Extensor Muscle* at the back of the wrist. Arising from the ulna and the interosseous membrane between the extensor secundi internodii pollicis and the extensor indicis, and passing under the annular ligament with the extensor communis, it divided into two tendons, the larger of which partly blended with the tendon of the extensor secundi internodii, and partly ended in the aponeurosis on the back of the first phalanx, while the smaller ended in the aponeurosis on the back of the index. The two tendons were united by a fibrous vinculum passing downward and inward from the former to the latter.

Mr W. H. BENNETT and Dr H. D. ROLLESTON showed two specimens of *Abnormalities around the Cæcum*.

Mr WILLIAM ANDERSON and Mr G. H. MAKINS read a paper on the *Subperitoneal and Subpleural Planes of Connective Tissue*, with their extensions.

INDEX TO PROCEEDINGS OF ANATOMICAL SOCIETY.

- ANDERSON, W., Subserous Connective Tissue, xix.
Aorta, Right, iv.
- BEER, BERTHOLD, Sylvian Fissure, ix.
Bennett, W. H., Abnormal Cæcum, xix.
Birmingham, Ambrose, Lumbar and Sacral Nerves in a Subject with Six Lumbar Vertebrae, i.
Bombinator, Spine of, xvi.
Brooks, H. St John, Anatomy of Abdomen, vii.
- CAGNEY, JAMES, Suspension of Spinal Column, xiii.
Calvaria of Tumbler, iv.
Cervical Ribs, iii.
Clarke, J. J., Abnormal Pulmonary Valve, viii.
Cleland, John, Fibro-plates and Inter-vertebral Discs, xiii.
Crania of Rabbit, xvii.
Cunningham, D. J., Intraparietal Fissure, x.
- EPIPHYSES, Ununited, viii.
- FRASER, ALEXANDER, Photography in Morphological Investigation, i; Nerve Terminations in Thyroid Gland, ii; Pyramidal Tracts in Rodents, ii.
- GRIFFITHS and Oliver, Cutaneous Nerves and Herpes, xi.
- HILL, WILLIAM, Pharyngeal Tonsil, xiv.
Howes, G. B., Kidney of *Raia clavata*, xix.
Howes, G. B., Spine of Bombinator, xvi; Crania of Rabbit, xvii.
- INTESTINE, Interruption of, xiii.
- JONES and Shore, Vertebrate Liver, vii.
- LIVER, Structure of, vii.
Lockwood, C. B., Interruption of Small Intestine, xiii.
Lockwood and Withers, Right Aortic Arch, iv.
- Lumbar Vertebra, Variations in, iii, xv.
- MAKINS, G. H., Subserous Connective Tissue, xix.
- NERVE Endings in Thyroid Gland, ii.
Nerves, Cutaneous, and Herpes, xi.
- OCCIPITAL Bone, with Odontoid Facet, xix.
Oliver and Griffiths, Cutaneous Nerves and Herpes, xi.
- PARSONS, F. G., Occipital Bone with Odontoid Facet, xix.
Paterson, A. M., Fracture of Cervical Vertebrae, ix.
Photography in Morphological Research, i.
Popliteal Artery, xix.
Pulmonary Valve, Abnormal, viii.
Pyramidal Tracts, ii.
- RABBIT, Crania of, xvii.
Reid, R. W., Cervical Ribs, iii; Abnormal Fifth Lumbar Vertebra, iii; Calvaria of Tumbler, iv.
Rodents, Pyramidal Tracts of, ii.
Rolleston, H. D., Abnormal Cæcum, xix.
Roughton, E. W., Sternalis Muscle, xiv.
- SHORE and Jones, Vertebrate Liver, vii.
Spinal Column, Suspension of, xiii.
Spine of Bombinator, xvi.
Sternalis Muscle, xiv.
Stewart, Charles, Pineal Eye, xv.
Sutton, Bland, Lumbar Vertebra, xv; Fallopian Tubes, xv.
Sylvian Fissure, Development of, ix.
- THYROID Gland, Nerve Endings in, ii.
- VERTEBRÆ, Cervical Fracture from Hanging, ix.
- WINDLE, B. C. A., Ununited Epiphyses, viii.
Withers, F. E., Popliteal Artery, xix.
Withers and Lockwood, Right Aortic Arch, iv.

Fig. 1.

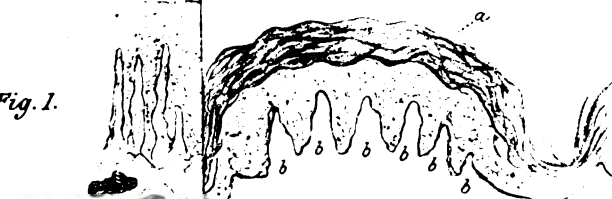


Fig. 4.



Fig. 11.



Fig. 5.

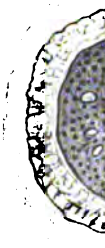


Fig. 10.

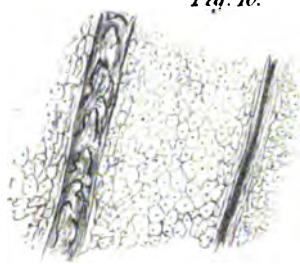


Fig. 1.



Fig. 2.

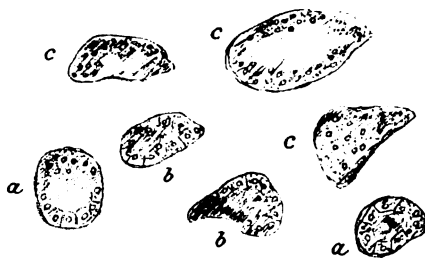


Fig. 3.

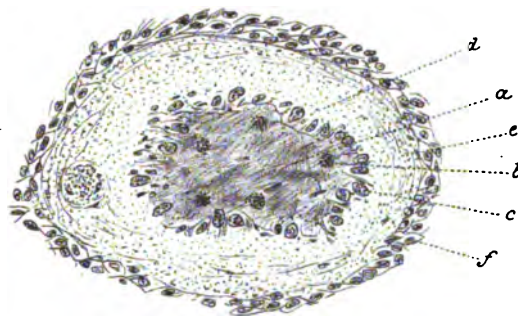
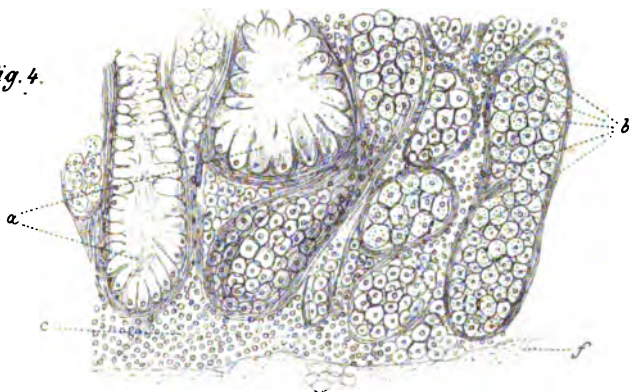


Fig. 4.



Sibley del.

F. Huth, Lithr. Edinr.

GIANT CELLS OF TUBERCLE.



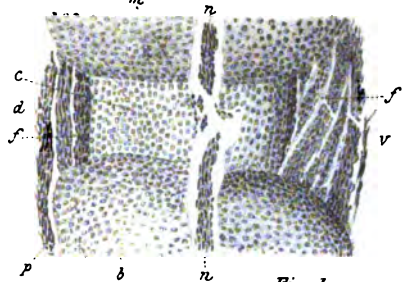


Fig. 1.



Fig. 4.

Fig. 2.

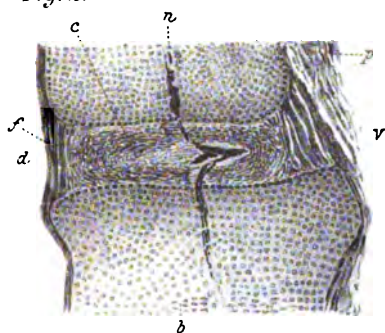


Fig. 5.

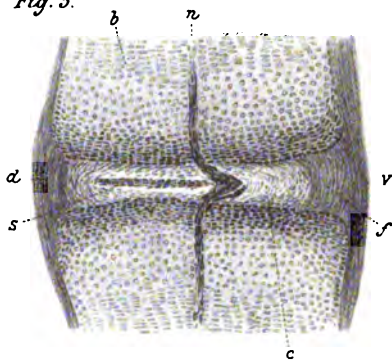


Fig. 3.

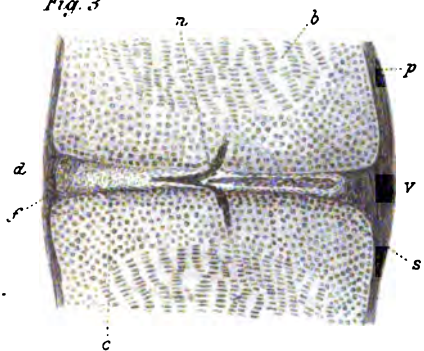


Fig. 6.

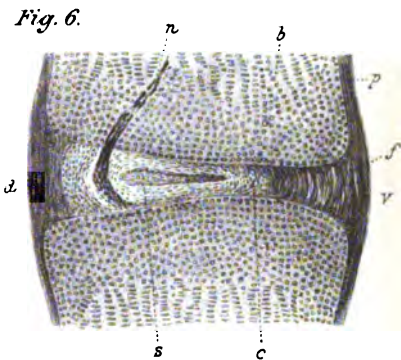
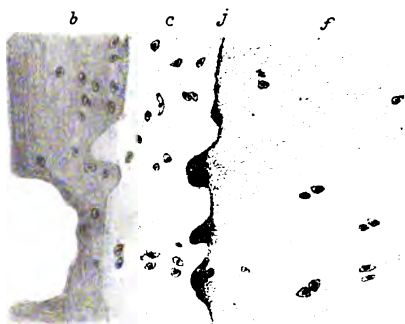


Fig. 7.



S. Fowler del.

F. Huth, Lith. Edin.

NOTOCHORD.



